ASSESSMENT OF THE EFFICACY OF CLEAR ALIGNER THERAPY FOR MAXILLARY EXPANSION

Dissertation submitted to

SANTOSH DEEMED TO BE UNIVERSITY, GHAZIABAD, NCR DELHI

In partial fulfillment of the requirement for the degree of

MASTER OF DENTAL SURGERY

In the Speciality of

ORTHODONTICS & DENTOFACIAL ORTHOPEDICS

Deemed to be University

(Established u/s 3 of the UGC Act, 1956)

By

Dr. PUJA KUMARI

Under the guidance of

Dr. RAJIV AHLUWALIA

Professor & Head

DEPARTMENT OF ORTHODONTICS & DENTOFACIAL ORTHOPEDICS

SANTOSH DENTAL COLLEGE & HOSPITALS

GHAZIABAD- 201009, NCR DELHI, INDIA

Batch 2022

© Santosh Deemed to be University , Ghaziabad, Uttar Pradesh

Deemed to be University

(Established u/s 3 of the UGC Act, 1956)

COPYRIGHT DECLARATION BY THE CANDIDATE

I, Dr. Puja Kumari hereby, declare that the **Santosh Deemed to be University, Ghaziabad, NCR Delhi** shall have the right to preserve, use and disseminate this dissertation in print or electronic format for academic or research purpose.

Date: **Dr. Puja Kumari**

Place:

Deemed to be University

(Established u/s 3 of the UGC Act, 1956)

DECLARATION BY THE CANDIDATE

I, Dr. Puja Kumari, declare that this dissertation entitled **"ASSESSMENT OF THE EFFICACY OF CLEAR ALIGNER THERAPY FOR MAXILLARY EXPANSION**" is a bonafide genuine research carried out by me under the esteemed able guidance of my guide **Dr. RAJIV AHLUWALIA, (MDS),** Professor & Head, Department of Orthodontics & Dentofacial Orthopedics, Santosh Dental College & Hospitals, Ghaziabad, NCR Delhi & co-guide **Dr. TINA CHUGH**, **(MDS),** Reader, Department of Orthodontics & Dentofacial Orthopedics, Santosh Dental College & Hospitals, Ghaziabad, NCR Delhi.

Date: **Dr. Puja Kumari**

Deemed to be University

(Established u/s 3 of the UGC Act, 1956)

ENDORSEMENT BY PRINCIPAL OF THE INSTITUTION

This is to certify that the dissertation entitled **"ASSESSMENT OF THE EFFICACY OF CLEAR ALIGNER THERAPY FOR MAXILLARY EXPANSION**" is a bonafide research work done by **Dr. PUJA KUMARI**, herself under the esteemed guidance of **Dr. RAJIV AHLUWALIA (MDS),** Professor & Head, Department of Orthodontics & Dentofacial Orthopedics, Santosh Dental College and Hospitals Ghaziabad, NCR Delhi.

Date:

Place:

(PROF.) Dr. AKSHAY BHARGAVA
DEAN
MDS (Prosthodontics)
AFAAID, DICOI, DWCOI
Santosh Dental College and Hospitals,
Ghaziabad, NCR Delhi

Deemed to be University

(Established u/s 3 of the UGC Act, 1956)

CERTIFICATE BY THE GUIDE

This is to certify that the dissertation entitled **"ASSESSMENT OF THE EFFICACY OF CLEAR ALIGNER THERAPY FOR MAXILLARY EXPANSION"** is a bonafide genuine research work carried out by **Dr. PUJA KUMARI** in partial fulfillment of the requirement for the degree of MASTER OF DENTAL SURGERY in the speciality of **Orthodontics & Dentofacial Orthopedics.**

GUIDE:

Dr. RAJIV AHLUWALIA
Professor and HEAD
Department of Orthodontics &
Orthodontics & Dentofacial Orthopedics
Santosh Dental College & Hospitals
Hospitals Ghaziabad, NCR Delhi.

CO-GUIDE:

Dr. TINA CHUGH
Reader
Department of
Dentofacial Orthopedics
Santosh Dental College &
Ghaziabad, NCR Delhi.

Deemed to be University

(Established u/s 3 of the UGC Act, 1956)

CERTIFICATE BY HEAD OF THE DEPARTMENT

This is to certify that the dissertation entitled **"ASSESSMENT OF THE EFFICACY OF CLEAR ALIGNER THERAPY FOR MAXILLARY EXPANSION"** being submitted by Dr. PUJA KUMARI in partial fulfillment of regulation for the award of the degree of Master of Dental Surgery in the specialty of Orthodontics & Dentofacial Orthopedics is based on the bonafide work carried out by her under my direct guidance and supervision and completed to my full satisfaction.

Dr. RAJIV AHLUWALIA
Professor and Head
Department of Orthodontics & Dentofacial Orthopedics
Santosh Dental College & Hospitals
Ghaziabad, NCR Delhi

Deemed to be University

(Established u/s 3 of the UGC Act, 1956)

ANTI- PLAGIARISM DECLARATION/UNDER TAKING

I, Dr. Puja Kumari hereby, declare that the present dissertation entitled **"ASSESSMENT OF THE EFFICACY OF CLEAR ALIGNER THERAPY FOR MAXILLARY EXPANSION"** submitted by me to Santosh Deemed to be University is a bonafide/original research work. I also hereby declare that there is no plagiarism and the present research work has not been submitted for the award of any degree/diploma of the same institution where the work was carried out or to any other institution.

Dr. Puja Kumari

I have verified the contents of the thesis and it is free from plagiarism.

Dr. Jyoti Batra

Date: **DEAN RESEARCH**

Place: Santosh Deemed To Be University

Dedicated to My Beloved family

& My father

Late

Dr Arvind Kumar

ACKNOWLEDGEMENTS

First and foremost, I would like to thank Almighty God for His endless grace, guidance, and strength throughout this journey. Without His divine support, none of this would have been possible. In moments of doubt, He gave me hope; in times of weakness, He gave me strength. For every blessing, seen and unseen, I am truly grateful.

I express my deepest gratitude to my most respected teacher and my guide ***Dr. RAJIV AHLUWALIA,*** *Professor and Head, Department of Orthodontics and Dentofacial Orthopedics, Santosh Dental College and Hospital, Ghaziabad, for his keen interest, precious and invaluable guidance during my course. His profound knowledge, insightful suggestions, and constructive feedback have played a crucial role in shaping this thesis.*

I extend my gratitude and thanks to my co-guide ***Dr. TINA CHUGH****, Reader, Department of Orthodontics and Dentofacial Orthopedics, Santosh Dental College and Hospital, Ghaziabad, for her constant encouragement and suggestions at every step in the formulation of this thesis without which this work would have remained a difficult job to accomplish. I am truly appreciative of her time, attention to detail, and willingness to assist at every step of the work. I am extremely grateful for her untiring help, invaluable guidance and affectionate attitude. I remain most indebt to her for her invaluable suggestions, her painstaking supervision, help and encouragement for my thesis. No amount of thanks and gratitude can equal all that she has done for me.*

I wish to express my sincerest regards to ***Dr. Akshay Bhargava****, Dean, Professor, Department of Prosthodontics & Crown and Bridge, Santosh Dental College & Hospitals, Ghaziabad, and other Respectable Members of Ethical Committee for permitting and providing me an opportunity to do thesis work in the Institution.*

*My special thanks to **Dr. Nishant Gupta**, Professor, Department of Orthodontics & Dentofacial Orthopedics, Santosh Dental College and Hospitals, Ghaziabad, for his valuable guidance, encouragement, and support throughout the course of this research. His deep knowledge, insightful feedback, and continuous motivation have been instrumental in the successful completion of this thesis. I am truly grateful for the opportunity to learn under his mentorship and for the time and attention he devoted to this work.*

*I wish to extend my thanks to **Dr. Mayank Gupta** Reader, Department of Orthodontics & Dentofacial Orthopedics, Santosh Dental College and Hospitals, Ghaziabad whose constant support and words of encouragement rejuvenated me to complete my research work.*

*I am also thankful to **Dr. Jyoti Batra**, Dean Research, Santosh University, Ghaziabad, for their kind help in completing my thesis work.*

*I am thankful to **Madhuri ji, Rajneesh ji and Pradeep Kumar**, our lab technician for their timely help and support in my laboratory work.*

*A sincere word of thanks to my seniors **Dr. Shivani Shukla, Dr. Hemlata Bajaj &, Dr. Palak Kulshresthha** who taught me as a friend and as a guide. I will always remember and cherish their guidance and friendship**.** I am extremely grateful to my colleague – **Dr. Amrit Singh, Dr. Komal Garje, Dr. Shambhavi Rajput & Dr. Nalin Yadav** –for making PG-life playful and for all their help in the times of need. Cheers to my juniors –**Dr. Adithya Nair, Dr. Harhsita Dabas, Dr. Priyanka Roy, Dr. Priyanka Thomas & Dr. Aditi Jain** who were always there to support me.*

Lastly and most importantly I would like to express my heartfelt gratitude to my family for their incredible support, encouragement, and love during my dissertation journey. I am deeply grateful to my parents, my in-laws ***Dr. Ram Pravesh Prasad & Dr. Renu Kumari****, who have been my rock throughout this journey. Their love and understanding have given me the strength to overcome any obstacle. This accomplishment is as much theirs as it is mine.*

I would like to express my deepest gratitude to my beloved husband, ***Dr Priyanshu Ranjan Sonoo,*** *for his unwavering support, patience, and understanding throughout this journey. His constant encouragement, emotional strength, and belief in my abilities have been a source of immense motivation. I am truly thankful for his sacrifices and for standing by me during every challenge faced during the course of this research. This work is as much a reflection of his support as it is of my effort, and I dedicate this milestone to him with deep affection and pride. I would like to extend my heartfelt gratitude to my children,* ***Amaira Singh & Atiksh Singh*** *whose love, patience, and understanding have been a constant source of strength throughout this journey. Their smiles, encouragement, and silent sacrifices have inspired me to persevere, even during the most challenging times. I would like to express my deepest gratitude to my mother* ***Mrs. Gita Kumari****, whose unwavering love, encouragement, and support made this possible. Her faith in me, even during the toughest times, gave me the strength to keep going. Thank you for always being my biggest cheerleader and for believing in me when I needed it most. I dedicate this work to the memory of my beloved father,* ***Dr Arvind Kumar*** *whose presence continues to guide me even in his absence. Though he is no longer here, his values, wisdom, and strength have stayed with me every step of the way. His quiet encouragement*

and belief in my potential still echo in my heart, pushing me forward when things got tough. This thesis is a tribute to all you gave me in life—and all you still give me in spirit. I hope I've made you proud.

I am also grateful to my younger brother, ***Mr. Anurag Kumar,*** *for his unwavering support and encouragement and my wonderful sister-in-law,* ***Mrs. Shabnam Sharma.*** *I would also like to thank my friends,* ***Dr. Manali Chakrabarty, Dr. Neha Rana, Dr. Nidhi Gupta & Dr. Sapna Goyal,*** *whose support, encouragement, and companionship have played a vital role throughout the course of this thesis. Their understanding, patience, and thoughtful conversations provided both comfort and motivation during challenging times. I am truly grateful for their presence and for the sense of balance and perspective they brought to this academic journey.*

I also thank all those who have contributed directly or indirectly in the completion of my thesis.

Dr. Puja Kumari

Contents

CONTENTS

TITLE	PAGE NO.
Introduction	1-6
Aim & Objectives	7-8
Review of Literature	9-37
Materials & Method	38-63
Results	64-99
Discussion	100-114
Conclusion	115-116
Summary	117-119
Bibliography	120-128
Annexures	129-136

LIST OF TABLES

TABLE NO.	TITLE	PAGENO.
1.	Test of Normality	74
2.	Interclass Correlation coefficient	75
3.	Descriptive Data of Linear transverse Measurement at T1, T2p and T2a	76
4.	Paired comparison of linear transverse measurement T1 and T2p	79
5.	Paired comparison of linear transverse measurement at T1 and T2a	81
6.	Paired comparison of linear transverse measurement at T2p and T2a	83
7.	Descriptive data of Inclination at T1, T2p and T2a	87
8.	Paired Comparison of Inclination at T1 and T2p	89
9.	Paired Comparison of Inclination at T1 and T2a	90
10.	Paired Comparison of Inclination at T2p and T2a	91
11.	Comparison of linear Transverse measurement T1 among Males Vs Females	92
12.	Comparison of linear Transverse measurement at T2p among Males Vs Females	94
13.	Comparison of linear Transverse measurement at T2a among Males Vs Females	95
14.	Comparison of Inclination T 1 among Right Vs Left	97
15.	Comparison of Inclination T 2p among Right Vs Left	98
16	Comparison of Inclination T2 among Right Vs Left	99

LIST OF GRAPHS

GRAPH NO	TITLE	PAGE NO.
1	Descriptive Data of Linear transverse Measurement at T1, T2p and T2a	77
2	Paired comparison of linear transverse measurement T1 and T2p	80
3	Paired comparison of linear transverse measurement at T1 and T2a	82
4	Paired comparison of linear transverse measurement at T2p and T2a	84
5	Percentage of Accuracy of Change in Linear Transverse measurement	85
6	Descriptive data of Inclination at T1, T2p and T2a	88
7	Paired Comparison of Inclination at T1 and T2p	89
8	Paired Comparison of Inclination at T1 and T2a	90
9	Paired Comparison of Inclination at T2p and T2a	91
10	Comparison of linear Transverse measurement T1 among Males Vs Females	93
11	Comparison of linear Transverse measurement at T2p among Males Vs Females	94
12	Comparison of linear Transverse measurement at T2a among Males Vs Females	96
13	Comparison of Inclination T 1 among Right Vs Left	97
14	Comparison of Inclination T 2p among Right Vs Left	98
15	Comparison of Inclination T2 among Right Vs Left	99

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO.
1	Intraoral Scanner	41
2	Asiga Max UV Dental Printer	42
3	d-tech 3D Accuprint resin	43
4	Washing Unit	43
5	Curing Unit	44
6	Eekodur-al Aligner sheets	44
7	Schue Pressure Moulding Machine Biostar	45
8	Themisto Digital vernier callipers	45
9	Degree Protector Professional Stainless Steel	46
10a	Linear Parameters	50
10b	Linear Parameters	51
11	Measurement of Intercanine Width	52
12	Measurement of First Interpremolar width	52
13	Measurement of Second interpremolar Width	53
14	Measurement of Mesial First Intermolar Width	53
15	Measurement of Distal First Intermolar Width	54

16	Measurement of Trans palatal First Molar	54
17	MeasurementofMesialSecondIntermolar Width	55
18	MeasurementofDistalSecondIntermolar Width	55
19	Measurement of trans palatal Second Molar	56
20	Measurement of Inclination of First Premolar (14)	56
21	Measurement of Inclination of Second Premolar (15)	57
22	Measurement of Inclination of First Molar(16)	57
23	Measurement of Inclination of First Premolar (24)	58
24	Measurement of Inclination of Second Premolar (25)	58
25	Measurement of Inclination of First Molar(26)	59

LIST OF ANNEXURES

NO.	TITLE	PAGE NO.
1	Patient Consent Forms	130-131
2	Master chart	132-134
3	Ethical Clearance Certificate	135
4	Anti- Plagiarism Report	136

LIST OF ABBREVIATIONS

NO.	ABBREVIATION	FULL FORM
1	3D	Three Dimensional
2	α	Alpha (Significance Level)
3	CAT	Clear Aligner Therapy
4	CBCT	Cone Beam Computed Tomography
5	CC	Crest of Cortical Bone
6	CEJ	Cementoenamel Junction
7	CAL	Clinical Attachment Level
8	df	Degrees of Freedom
9	GI	Gingival Index
10	G*Power	General Power Analysis Software
11	ICC	Intraclass Correlation Coefficient
12	ICW	Intercanine Width
13	IPR	Interproximal Reduction
14	IM1DC	Distal First Intermolar Width
15	IM1MC	Mesial First Intermolar Width
16	IM2DC	Distal Second Intermolar Width
17	IM2MC	Mesial Second Intermolar Width
18	IPM1W	First Interpremolar Width
19	IPM2W	Second Interpremolar Width

20	mm	Millimeter(s)
21	n	Number of Observations
22	p	p-value (Probability)
23	PI	Plaque Index
24	PPD	Probing Pocket Depth
25	RME	Rapid Maxillary Expansion
26	SARPE	Surgically Assisted Rapid Palatal Expansion
27	SD	Standard Deviation
28	SME	Slow Maxillary Expansion
29	SPSS	Statistical Package for the Social Sciences
30	STL	Standard Tessellation Language (3D file format)
31	T1	Pre-treatment Stage
32	T2a	Post-treatment Achieved (Clinical outcome)
33	T2p	Post-treatment Planned (Digital outcome)
34	TMD	Temporomandibular Disorder
35	TP M1	Transpalatal First Molar Width
36	TP M2	Transpalatal Second Molar Width
37	UV	Ultraviolet
38	$\bar{x}$	Mean of Sample Values
39	$\bar{x}$diff	Mean of Differences Between Pairs
40	s	Sample Standard Deviation

41	sdiff	Standard Deviation of Differences
42	δ	Noncentrality Parameter
43	d	Cohen’s d (Effect Size)

Introduction

INTRODUCTION

Malocclusions can occur in all three planes: sagittal, transverse, and vertical. The most prevalent type of maxillary discrepancies are transverse ones.[1] When treating adolescents and adults, the most common issue an orthodontist encounters is a constricted upper arch. Clinical characteristics of transverse maxillary abnormalities include crowding in anterior teeth, a deep or narrow palatal vault, a V-shaped palate, and posterior crossbite, which can occur on one or both sides.[2] Laptook recognized fundamental clinical characteristics in a case of a full crossbite, such as nasal breathing difficulties, decreased nasal cavity volume due to elevation of nasal floor, a narrow hard palate, enlarged nasal turbinate, the narrowing of the pharyngeal airway, alterations in the tongue posture and mouth breathing.[3] Skeletal or dentoskeletal malocclusion is indicated by the presence of at least two of the previously listed clinical characteristics, necessitating treatment that aims to increase the transverse maxillary measures.[2,3]

The correction of transverse discrepancies typically necessitates the expansion of the palate through a synergistic approach involving both orthopedic and orthodontic tooth movements. Maxillary expansion treatments have been used for more than a century to correct maxillary transverse deficiency.[4] In 1723, the first orthodontic appliance 'Bandelette' was developed by Pierre Fauchard for expansion in anterior region.[5] Emerson C. Angell invented this process in New York in 1860. A girl of 14½ years old had her arch enlarged by a quarter inch in two weeks after he inserted a screw device between her maxillary premolars.[6]

Nowadays, there are three expansion treatment modalities: slow maxillary expansion (SME), rapid maxillary expansion (RME), and surgically assisted maxillary expansion.[4]

Slow Maxillary Expansion (SME) is an orthodontic technique used to correct transverse maxillary deficiency by gradually widening the upper arch through continuous, light force application over an extended period.[7] Rapid Maxillary Expansion (RME) aimed at separating the midpalatal suture to increase maxillary width. This approach is particularly effective in children and adolescents, where the midpalatal suture remains flexible.[8] Surgically Assisted Rapid Palatal Expansion (SARPE) is a combined surgical and orthodontic approach designed for adults with fused midpalatal sutures, where traditional RME is ineffective.[9]

The advantages of SME include gentler force application, reduced risk of root resorption, improved stability, and precise control over expansion. However, disadvantages include prolonged treatment duration, limited efficacy in adults with fully fused sutures, and the need for patient compliance. Despite these challenges, SME remains a valuable option for managing maxillary constriction, enhancing occlusion, and improving facial aesthetics.[10] In a 2020 study by Pinheiro et al[11] it was concluded that SME offers better long-term stability than rapid expansion in growing children. The gradual force reduces the risk of complications, such as the tipping of teeth, which are more common with rapid techniques. Additionally, Colak c et al [12] compared the clinical outcomes of SME with RME and found that while RME provides faster results, SME has the advantage of being associated with fewer adverse effects, such as root resorption and periodontal issues.

These slow and rapid treatment modalities of maxillary expansion has been carried out by bulky appliances placed in the palatal area like quad helix, NiTi palatal expander, Haas-type expanders, Hyrax, Schwartz appliance and expansion screws.[7,8] These appliances encroach in the tongue space and hinder the tongue movements thus causing discomfort to the patient along with the biomechanical consideration of buccal tipping of teeth.[13] The

ongoing research for innovation in orthodontics has boosted the emergence of appliances designed to offer patients more comfort, less chair time, a shorter treatment time, ability to secure better oral hygiene, greater patient acceptance and better post treatment stability.[14]

In contemporary society, many people believe that malocclusion adversely affects individuals' physical, social, and psychological health. Patients pursue orthodontic care to enhance their appearance, improve oral function, boost psychosocial health, and elevate their quality of life, with the primary reason for adult patients seeking such treatment being the enhancement of their appearance. Nonetheless, brackets may lead to an unappealing look, functional challenges, discomfort, and pain during the treatment process. The desire for esthetic dentistry has surged in recent years, resulting in an increasing number of adult patients opting for more aesthetically pleasing brackets. Ceramic brackets, lingual brackets, and clear aligners have been developed to enhance the esthetic aspect of treatment.[15]

Clear aligner treatment (CAT) is an Invisible' way of straightening teeth without using antiquated metallic braces and wires. It utilizes aligners to create clear, personalized aligners designed to gradually and methodically move teeth into their ideal positions using computer- aided technology. Each aligner is programmed to move a tooth or a small group of teeth 0.25 to 0.33 mm every 14 days.[16] In order for aligners to be successful, patients must wear them for at least 20 to 22 hours per day and take them off only to eat, drink, or clean their teeth.[16]

Clear aligner therapy was initially used to address minor dental spacing and alignment. However, with advancements in aligner materials, attachment design and 3-dimensional software, treatment of various types of malocclusions has become conceivable. Mild

crowding (1–5 mm), spacing issues (1–5 mm), deep overbites (Class II, div. 2), narrow arches needing expansion, absolute intrusion (one or two teeth), severe crowding with lower incisor extraction, and molars needing distal tipping are generally the indications for CAT.[16,17]

Patients and clinicians have been drawn to clear aligners for a number of reasons, such as safety, cosmetic appeal, comfort, ease of maintaining gingival/periodontal health and superior oral cleanliness.[18,19] Based on multiple studies,[20,21] it was determined that clear aligners reduced treatment times for patients with mild to moderate crowding (1-6 mm), mild to moderate spacing (1-6 mm), non- skeletal restricted arches and non-extractions. The majority of complex cases or extractions require root torquing or uprighting movement, which is challenging to do with clear aligners.[22]

Since the introduction of clear aligner treatment (CAT) as an esthetic alternative to traditional orthodontics, it has been reported that CAT was able to correct dentoalveolar cross bite and to achieve inter- arch transverse coordination. A systematic review Lopez et al concluded that aligner is able to alter intercanine, interpremolar, and intermolar width in the presence of crowding.[23] CAT was able to correct dentoalveolar crossbite and to achieve interarch transverse coordination. In traditional fixed appliances, maxillary expansion is achieved through the buccal tipping of teeth in both the anterior and posterior areas. In contrast, the CAT system facilitates the digital planning of upper arch expansion by employing a dual approach that includes buccal dental tipping alongside the bodily translation of the posterior teeth. However, several authors have agreed that more dental tipping than bodily translation was clinically observed.[24,19]

The current study aimed to evaluate the effectiveness and predictability of clear aligner therapy (CAT) in achieving maxillary expansion by comparing the digitally planned transverse expansion with the actual clinical outcomes.

Aim & Objectives

AIM AND OBJECTIVES

AIM

The aim of the present study is to investigate the effectiveness of clear aligner therapy in maxillary arch expansion.

OBJECTIVES

1. To evaluate the transverse dental dimensions—specifically intercanine width (3-3), interpremolar width, and intermolar width—in pretreatment models (T1).
2. To assess the planned transverse changes in intercanine, interpremolar, and intermolar width in the digital treatment plan at the end of 16 weeks (T2p).
3. To measure the actual changes achieved clinically in intercanine, interpremolar, and intermolar widths, and molar inclination on final models obtained three months post-expansion (T2a).
4. To compare the effectiveness of maxillary expansion by analyzing the differences between the planned (T2p) and achieved (T2a) outcomes.
5. To assess the inclination changes of the premolar and the molar between planned and achieved changes.
6. To evaluate the effectiveness of the aligners in male versus female patients.

RESEARCH HYPOTHESIS

Expansion achieved clinically is less than planned digitally.

NULL HYPOTHESIS

There is no difference between planned and achieved expansion in clear aligner therapy.

Review of Literature

REVIEW OF LITERATURE

1. **Boyd RL, Waskalic V (2001)[25]** provided one of the earliest comprehensive evaluations of the Invisalign® system, demonstrating its potential beyond mild to moderate malocclusions. Their study showcased the use of 3D digital technology for precise diagnosis and treatment planning through ClinCheck® software, enabling controlled tooth movements via sequential aligners.They eported successful treatment outcomes in cases involving Class II and III corrections, extractions, deep bites, and dental expansion. Key benefits included enhanced esthetics, hygiene, and patient comfort, along with high compliance. However, limitations were noted in achieving certain movements, such as extrusion, rotation of rounded teeth, and bodily movement, often requiring bonded attachments and overcorrections. They proposed that complex cases may still necessitate adjunctive use of fixed appliances and highlighted the importance of clinician experience and case selection. They established the conclusion that with proper planning, clear aligners could serve as a viable alternative to fixed appliances in selected complex cases. Their work laid the foundation for further research and technological advancement in aligner-based orthodontic therapy, emphasizing the importance of biomechanical understanding and digital tools in modern orthodontics.

2. **Ali O, Gonzalez M, Kimme-Smith C et al (2012)[26]** investigated the effectiveness of Invisalign® clear aligners in achieving dentoalveolar expansion, particularly in non-extraction cases requiring transverse development. Their study evaluated pre- and post- treatment dental casts to assess arch width changes and confirmed that significant expansion could be achieved using Invisalign, primarily

through buccal tipping of posterior teeth. The results demonstrated that Invisalign aligners were capable of producing clinically relevant increases in intercanine, interpremolar, and intermolar widths. However, the study noted that much of the expansion achieved was dentoalveolar rather than skeletal, indicating that bodily movement was limited and most changes were due to crown tipping. Ali et al. concluded that clear aligner therapy, when properly planned, can effectively produce transverse arch development in mild to moderate crowding cases. They emphasized the importance of careful digital planning and the potential need for overcorrection to account for underexpression of programmed movements. This study supports the use of Invisalign as a non- invasive method for arch expansion in selected cases.

3. **Zhao X, Wang HH, Yang YM et al (2017)[27]** conducted a study aimed at assessing the effectiveness of maxillary expansion using clear aligners and examining potential influencing factors. The study included thirty-one cases of clear aligners (Invisalign) that underwent maxillary expansion. Three-dimensional (3D) digital models were collected for pre-treatment, treatment plans created in Clincheck software, and post-treatment evaluations. Measurements were taken for upper dental arch width, the buccal inclination of posterior teeth, and the efficiency of expansion (actual expansion achieved versus planned expansion). The increases in upper arch width for the canine, first and second premolars, and first and second molars were recorded as (2.0±1.3), (2.8±1.5), (3.0±1.4), (1.8±1.0), and 0.5 (0.1, 1.1) mm, with corresponding efficiencies of 68%, 70%, 68%, 55%, and 29%, respectively. They concluded that the posterior teeth exhibited a significantly greater buccal inclination compared to the intended position.

4. **Houle JP, Piedade L, Todescan R Jr et al** (**2017**)[28] conducted a study aimed at assessing the predictability of arch expansion utilizing Invisalign. The study involved sixty-four adult Caucasian patients and was retrospective in nature. Digital models, both pre- and post-treatment, were generated from an iTero scan by a single orthodontic practitioner. Additionally, digital models from Clincheck were sourced from Align Technology. Measurements of upper and lower arch widths were taken for canines, premolars, and first molars at two distinct points: the lingual gingival margins and the cusp tips. The findings indicated that the average accuracy of the planned expansion for the maxilla using Invisalign was 72.8%, while the lower arch demonstrated an overall accuracy of 87.7%. It was noted that Clincheck tends to overestimate expansion due to body movement, resulting in increased tipping.

5. **Solano-Mendoza B, Sonnemberg B, Solano-Reina E et al (2017**)[29] investigated the efficacy of the Invisalign® system in facilitating expansion movements using Ex30' aligners. The research involved a cohort of 116 patients who underwent expansion treatment with Invisalign®. The study assessed various parameters at two time points, T1 and T2, utilizing 3D models and ClinCheck® software. The measured variables included canine gingival width, first and second premolar gingival widths, first molar gingival width, canine and premolar cuspid widths, canine depth, arch depth, and the rotations and inclinations of the first molars. The analysis revealed statistically significant differences in several parameters, including canine gingival width and various cuspid widths, when comparing the 3D model to ClinCheck® at T2. The authors concluded that the anticipated expansion outcomes at the conclusion of treatment were not reliably predictable.

6. **Zhou N and Guo J (2020)[30]** conducted a research study aimed at examining the effectiveness and movement dynamics associated with upper arch expansion utilizing Invisalign aligners. The study involved twenty adult patients from China who received arch expansion treatment with these aligners. Data was gathered at two key points: the pre-treatment stage (T0) and immediately following the completion of the expansion phase (T1). This data collection included digital models and cone-beam computed tomography scans. To analyze the data and assess the discrepancies between anticipated and actual results, Dolphin 3D, Geomagic Studio 12.0, and Measure software were utilized. The findings revealed that the average efficiency of bodily expansion movement for the maxillary first molar was 36.35 ± 29.32%. The researchers concluded that the Invisalign system is capable of enhancing arch width tipping movement of posterior teeth, with the average efficiency of bodily buccal expansion for maxillary first molars being 36.35%.

7. **Fiori A, Minervini G, Nucci L, d'Apuzzo F (2020)[31]** evaluated the predictability of crowding resolution and the effectiveness of various strategies for creating space during treatment with clear aligners. The findings indicated a high predictability of crowding resolution, with rates of 87% in the upper arch and 81% in the lower arch. Among the strategies employed to create space, alterations in the sagittal position of incisors were found to be predictable, achieving a consistency of 70% in both arches. In contrast, modifications in arch diameters exhibited lower reliability, ranging from 49% to 67% in the lower arch and from 59% to 83% in the upper arch. Furthermore, interproximal reduction (IPR) demonstrated the least accuracy, with predictability rates of 49% in the upper arch and 42% in the lower arch.

8. **Sun P and Xin Y (2020)**[32] examined 15 patients aged 8 to 11 years to investigate maxillary and mandibular arch expansion associated with clear aligner therapy (CAT). Utilizing a three- dimensional digital oral scanner, a digital model was created to monitor treatment progress pre- and post-intervention. The results revealed that arch expansion was most pronounced in the maxillary canine area and least effective in the maxillary first molar region. The authors concluded that the effectiveness of aligners in achieving arch expansion could be improved through the use of attachments and the application of desired torque to regulate tooth movements .

9. **Morales-Burruezo I, Gandía-Franco JL, Cobo J, Vela-Hernández A et al (2020)**[33] conducted a cohort study of 114 patients suffering from transverse malocclusion underwent treatment utilizing SmartTrack. The reliability of the system's software, Clincheck, was evaluated by juxtaposing the anticipated measurements—namely the widths of canines, premolars, and the rotations and inclinations of molars—with the actual measurements obtained at the conclusion of the initial treatment phase. The findings indicated that significant improvements in widths were achieved through the treatment. Specifically, the virtual planning predicted greater expansion than what was ultimately realized, with an average excess of 0.63 mm at the canine level ($p<0.001$), 0.77 mm at the first premolar ($p<0.001$), 0.81 mm at the second premolar ($p<0.001$), 0.69 mm at the first molar ($p<0.001$), and 0.25 mm at the second molar ($p = 0.183$). They concluded that aligners serve as an effective means for facilitating arch expansion, demonstrating superior efficacy in the premolar region while being less effective in the canine and second molar regions.

10. **Barreda GJ, Dzierewianko EA, Mazza V et al (2020)[34]** undertook a study aimed at assessing alterations in periodontal health and maxillary buccal bone by analyzing both clinical and tomographic parameters throughout the first year of orthodontic expansion using Invisalign® aligners. The upper first (1PM) and upper second (2PM) premolars of 19 patients requiring orthodontic expansion were scrutinized. Data on plaque index (PI), gingival index (GI), probing pocket depth (PPD), clinical attachment level (CAL), and cone beam tomographic (CBCT) records were gathered at 76 sites prior to the initiation of treatment (T0) and after 12 months (T1). Bone height was quantified from the cementoenamel junction (CEJ) to the crest of the cortical bone (CC), while bone thickness was assessed at two levels: 4 mm (CEJ+4) and 6 mm (CEJ+6) apical to the CEJ. A descriptive analysis was performed to observe variations in bone thickness and height across the cases. The mean expansion recorded was 1.93 mm for 1PM and 1.67 mm for 2PM. The arithmetic mean distance from CEJ to CC in 1PM was 3.05 mm at T0, which remained unchanged at 3.05 mm at T1.

11. **Horani S, El-Bialy T, Barmak AB et al (2021)[35]** conducted a retrospective analysis to examine alterations in airway dimensions resulting from non-extraction clear-aligner therapy (NE-CAT) in adult patients experiencing mild to moderate crowding. The study evaluated cone-beam computed tomographic images of 24 adults (16 females and 8 males) with mild to moderate crowding and either Class I or mild skeletal Class II malocclusion, both prior to and following NE-CAT. Measurements of the airway were taken cross-sectionally and volumetrically at the nasal cavity, upper pharyngeal airway space (UAS), and lower pharyngeal airway space (LAS). The findings indicated that NE-CAT does

not lead to improvements in airway dimensions for adults with mild to moderate crowding.

12. **Levrini L, Carganico A, Abbate L et al (2021)[36]** conducted a study to assess changes in the maxillary arch of patients treated with Invisalign® during the mixed dentition phase, focusing on arch width, arch perimeter, arch depth, molar inclination, and alveolar expansion. The study involved 20 patients, comprising 12 females and 8 males, who received clear aligners for maxillary expansion. Measurements of arch width, arch perimeter, arch depth, and molar inclination were taken from digital dental models before and after treatment. Superimposition of these digital models was utilized to assess alveolar expansion. The results demonstrated significant increases in both arch width and arch perimeter, while arch depth and molar inclination exhibited significant reductions. The findings suggest that Invisalign® First clear aligners could serve as an effective alternative to traditional slow maxillary expanders in cases of mild crowding or minimal transverse maxillary deficiency.

13. **Lione R, Paoloni V, Bartolommei L et al (2021)[37]** conducted a research study aimed at assessing the development of the maxillary arch utilizing the Invisalign system. The participant group comprised 28 individuals (16 females and 12 males) with a mean age of 31.9 ± 5.4 years. The inclusion criteria specified European ancestry, a posterior transverse discrepancy ranging from 3 to 6 mm, a permanent dentition stage, the presence of second permanent molars, mild to moderate crowding, and a high level of compliance with the aligners. The treatment protocol involved non-extraction methods, the application of the Invisalign clear aligner system, and the use of no auxiliaries apart from Invisalign attachments.

Linear and angular measurements were taken prior to treatment (T1), at the conclusion of treatment (T2), and on the final virtual models (T2 Clin Check). The most significant increase in maxillary width was observed at the upper first and second premolars, with increases of +3.5 mm for the first premolar and +3.8 mm for the second premolar at T2. A comparison of angular outcomes from T2 to T1 revealed statistically significant changes in the inclinations of all teeth, with the exception of the second permanent molars. The researchers concluded that the development of the maxillary arch exhibited a gradual reduction in buccal tipping and expansion rates across the anterior, lateral, and posterior regions, with the first and second premolars demonstrating the most substantial net increase.

14. **Vidal-Bernárdez ML, Vilches-Arenas Á, Sonnemberg B et al (2021)[38]** conducted a study to evaluate the effectiveness and predictability of maxillary and mandibular expansion using the Invisalign® system. From a total sample of 167 patients, 64 upper and 51 lower arches were randomly selected from those treated with plastic orthodontics (Invisalign® aligners made from SmartTrack® material). Digital models were created at the start (ModT1) and conclusion of treatment (ModT2), as well as the final ClinCheck® (CkT2). Measurements were taken of the canine, premolar, and molar widths at both the gingival and cuspid levels of both arches, in addition to the inclination of the upper first molar. The findings indicated that the Invisalign® system aligners (constructed from SmartTrack® material) demonstrated efficacy in both upper and lower arches.

15. **Cretella Lombardo, E Paoloni, V Fanelli et al (2022)[39]** conducted a study aimed at examining the morphological alterations of the upper arch following two expansion protocols: the Invisalign® First system and rapid maxillary expansion

(RME) in mixed dentition, utilizing geometric morphometric analysis (GMM). Digital dental casts were obtained from 32 children, divided into two groups: the RME group consisting of 17 subjects with a mean age of 8.1 years, and the First group with a mean age of 8.4 years. Pre-treatment (T1) and post-treatment (T2) digital models were generated for both groups. A total of 14 landmarks were digitized, and GMM was employed, followed by Procrustes analysis and principal component analysis (PCA). The findings revealed statistically significant morphological changes in the posterior region of the upper arch shape, while no significant variations were observed in the anterior region.

16. **Perrotti G, Carrafiello A, Rossi O et al (2022)[40]** conducted a retrospective study to evaluate the efficacy of the Nuvola® OP System, an orthodontic method that integrates clear aligners with a morpho-functional corrector worn for 30 minutes daily. This combined approach was designed to address cases that are typically difficult to manage with aligners alone. Linear measurements were extracted from STL files of 100 patients, and for a subset of 77 patients aged 18 to 55 years (mean age 28.6 ± 16.2 years), 3D superimpositions of intraoral scans taken pre- and post- treatment were analyzed to quantify maxillary expansion. The most significant expansion was observed at the first molars, with an average increase of 2.35 ± 1.64 mm. Patient-reported outcomes were positive, with 96% expressing satisfaction and 90% indicating ease in adhering to the prescribed protocol. The study demonstrated a statistically significant expansion of the maxillary arch, particularly at the first molars (2.00 ± 1.65 mm for trimmed STL files and 3.01 ± 1.60 mm for untrimmed STL files).

17. **Pan B, MacIntosh D, Njie R, Lui A et al (2022)[41]** conducted research on13 pediatric patients aged 6 to 13 years who received orthodontic treatment with clear aligners were analyzed. The treatment protocol included maxillary arch expansion, and both pre- and post-treatment CBCT (Cone Beam Computed Tomography) scans were reviewed as part of the standard orthodontic documentation. Additionally, a control group of 8 children aged 7 to 12 years, who did not receive aligner treatment but underwent two CBCT scans, was included for comparative analysis. The objective of the study was to assess whether the application of clear aligners in pediatric patients resulted in notable alterations in upper arch width and nasal airway volume and morphology. Furthermore, a retrospective pilot study was performed involving 6 adult patients aged 31 to 52 years, who underwent similar maxillary expansion treatment with clear aligners. The results demonstrated a significant increase in both nasal airway volume and intermolar width within the pediatric treatment group, whereas no such changes were noted in the control group. The authors concluded that clear aligner therapy with upper arch expansion may represent a promising strategy for enhancing airway function, potentially offering benefits to patients suffering from obstructive sleep apnea (OSA).

18. **D'Antò V, Valletta R, Di Mauro L et al (2023)[42]** conducted a study examining the impact of maxillary orthodontic expansion on the alveolar bone tissue in adult patients undergoing treatment with aligners, utilizing cone-beam computed tomography. The study involved thirty participants (22 females and 8 males; average age 36.3 years) who were treated with Invisalign® aligners. Cone-beam computed tomography scans and digital models were collected prior to (T0) and

following (T1) the expansion of the upper arch. Measurements of bone thickness were taken in the cervical, middle, and apical regions of the incisors, canines, premolars, and first molars, resulting in a total of 96 areas and 2,880 measurements. Additionally, buccolingual inclinations and transverse measurements of the teeth were derived from digital models to establish correlations with the observed bone changes. The CBCT analysis indicated an increase in bone tissue around the second premolars, followed by the first molars, central incisors, lateral incisors, canines, and first premolars prior to treatment. Post-maxillary expansion, there was no significant reduction in the thickness of the alveolar bone across any of the evaluated teeth on either side.

19. **Galluccio G, De Stefano AA, Horodynski M et al (2023)[43]** evaluated the effectiveness and precision of maxillary arch expansion utilizing Clear Aligner Treatment. The study involved 28 participants with an average age of 17 ± 3.2 years. All selected patients underwent treatment using the Invisalign® clear aligner system without any auxiliaries, apart from the Invisalign® attachments; no tooth extractions or interproximal enamel reductions (IPR) were performed. Linear measurements of the expansion were taken prior to treatment (T0), at the conclusion of treatment (T1), and on final virtual models via Clin Check® (TC). A paired t-test was employed to analyze the differences between T0-T1 and T1-TC. The Shapiro-Wilks test was employed to verify the normality of the data, revealing an average efficacy accuracy of 70.88%. While the differences in predictability among various vestibular measurements (inter-canine, inter-premolar, and intermolar) were not statistically significant, they were significant for gingival measurements. The overall accuracy of the expansion treatment was determined to be 70%, irrespective of the type of tooth.

20. **Bouchat M, Saade A, El Helou M et al (2023)[46]** examined the impact of arch expansion utilizing clear aligners, with a particular emphasis on the unintended effect of buccal flare in the posterior dentition. The research highlighted the importance of implementing an appropriate torque compensation angle, taking into account the patient's existing condition and adherence, to mitigate the buccal tipping of posterior teeth. It was observed that the effect of varying torque compensation on the inclination of posterior teeth diminished from the first premolar to the second molar. They concluded that following the introduction of torque compensation, there was a notable reduction in the degree of buccal tilt in the posterior teeth, with some instances of palatal tilt emerging.

21. **Suzuki S, Nakano H, Kataoka Y et al (2023)[19]** conducted a study to find the clear aligner form which buccal tipping is less likely to occur by experimentally comparing the marginal type of the aligners with the orthodontic force and conformity (flotation) on the first molars during lateral expansion. Materials and methods: Four different marginal types (conventional aligners with no palatal coverage, partial palatal coverage [with or without 2.0 mm buccal extension], and complete palatal coverage) and three levels of lateral expansion (no expansion, 0.25-mm expansion, and 0.50-mm expansion) were used. The force applied to the first molar was measured by attaching a pressure sensor to the palatal side of the left first molar on a modelled maxillary constricted dental arch. At 0.50-mm expansion, the partial, buccal, and complete-coverage aligner types exerted greater forces than the conventional aligner ($p < 0.01$). Furthermore, the complete-coverage aligner produced significantly higher forces ($p < 0.01$) than the partial and buccal types. Conventional aligners should have greater buccal tipping of the

molars due to increased flotation with expansion. Complete palatal coverage aligners with 0.25-mm expansion had the best conformity, suggesting that they may prevent unplanned buccal tipping of the molars and allow lateral expansion to occur as intended.

22. **Zhang Y, Hui S, Gui L et al (2023)[20]** investigated the effects of arch expansion with clear aligners, focusing on the unintended consequence of buccal flare in posterior teeth. This study emphasized the necessity of applying an appropriate torque compensation angle, considering the patient's current status and compliance, to counteract buccal tipping of the posterior teeth. The influence of different torque compensation on the degree of posterior tooth inclination also decreased from the first premolar to the second molar. After torque compensation was added, the degree of buccal tilt in the posterior teeth was reduced and even palatal tilt appeared.

23. **Yao S, Jiang W, Wang C, He Y et al (2023)[47]** conducted a finite element analysis (FEA) to evaluate the biomechanics of clear aligner therapy during dentoalveolar arch expansion, with a focus on improving tooth movement efficiency and torque control. The study aimed to address the common limitation of buccal tipping during aligner- induced expansion and explore methods to promote more controlled, bodily tooth movements. They created detailed 3D finite element models of the maxillary dentition, alveolar bone, periodontal ligament, and clear aligners. Different clinical scenarios were simulated, including expansion with and without the use of optimized attachments and torque-control strategies. The models were used to measure stress distribution, displacement patterns, and the degree of root control during simulated expansion movements.

The analysis revealed that aligner-based expansion, when performed without auxiliary features, resulted primarily in crown tipping with limited root movement. However, the incorporation of optimized attachments and improved aligner designs enhanced torque control, resulting in more favourable stress distribution and more efficient bodily tooth movement. They concluded that while clear aligners can effectively expand the dental arch, the predictability and quality of the movement depend heavily on biomechanical optimization. Their findings underscore the importance of treatment planning, including the strategic use of attachments and overcorrection, to achieve controlled, stable outcomes in transverse expansion.

24. **Figueiredo MA, Romano FL, Feres MFN et al (2023)[48]** investigated the effects of dentoalveolar expansion using clear aligners on the maxillary alveolar bone in adult patients, utilizing cone-beam computed tomography (CBCT) for precise evaluation. The study aimed to assess whether transverse expansion with aligners compromises alveolar bone integrity, a critical concern in adult orthodontics due to limited skeletal adaptability. The methodology involved a retrospective analysis of CBCT scans taken before and after clear aligner treatment in adult patients who underwent maxillary expansion. The sample size was 32 pts with mean age of 36.3 years. Linear measurements were performed to evaluate changes in buccal bone thickness and alveolar crest height in the premolar and molar regions. The results demonstrated that while clear aligners effectively achieved transverse dental expansion, there was a statistically significant reduction in buccal bone thickness at specific sites. However, the magnitude of bone loss remained within clinically acceptable limits, and no cases of dehiscence or fenestration were

reported. They concluded that dentoalveolar expansion with clear aligners is generally safe for adults when carefully planned, although clinicians must remain cautious of potential alveolar bone compromise, especially in patients with thin cortical bone. This study reinforces the importance of using CBCT for pre-treatment planning and post-treatment monitoring to ensure periodontal health during aligner-based expansion.

25. **Nogal-Coloma A, Yeste-Ojeda F, Rivero-Lesmes JC a et al (2023)[49]** assessed the predictability of maxillary dentoalveolar expansion using clear aligners in patients with different types of crossbites. The study focused on determining how accurately planned transverse movements using aligner software translate into clinically achieved outcomes, particularly in posterior crossbite cases. The cohort comprised 46 patients aged between 20 and 60 years, categorized into 15 with unilateral, 15 with bilateral, and 16 with single-tooth crossbite.They conducted a retrospective analysis of digital models before and after treatment and compared the predicted outcomes from ClinCheck® (Invisalign software) to the actual achieved expansion in patients with unilateral, bilateral, or no crossbite. Measurements were taken at the canine, premolar, and molar levels. The findings revealed that while clear aligners are capable of achieving dentoalveolar expansion, there was a consistent under expression of the planned movements, especially in bilateral crossbite cases. The predictability was highest at the canine level and decreased progressively toward the molars. They concluded that although aligners can effectively address transverse discrepancies, overcorrection should be incorporated into digital treatment planning to account for the reduced expression of programmed expansion— especially in more severe or bilateral

crossbite cases. This study highlights the importance of individual case assessment and careful planning to improve the reliability of aligner-based expansion.

26. **Rocha AS, Gonçalves M, Oliveira AC, Azevedo RM et al (2023)[50]** evaluated the efficiency and predictability of maxillary coronal expansion using clear aligner therapy. The study aimed to assess how closely the achieved expansion matched the planned outcomes, focusing on coronal width changes in the premolar and molar regions. The study included patients treated with Invisalign®, and digital dental models were analysed pre- and post-treatment using specialized software. The planned expansion from the ClinCheck® software was compared to the actual clinical results, allowing for the assessment of predictability. Results showed that while clear aligners successfully achieved transverse expansion, there was a consistent under expression of the programmed movements—especially in the posterior region. The greatest discrepancy was observed at the first molars, whereas expansion at the premolar level was more predictable. They concluded that although clear aligners can effectively produce maxillary expansion, overcorrection should be considered during treatment planning to compensate for biomechanical limitations. Their findings reinforce the importance of aligning digital planning with clinical expectations to improve treatment predictability.

27. **Keilig L, Brieskorn L, Schwarze J et al (2024)[51]** conducted a study examining the efficacy of orovestibular tooth movement utilizing aligners and employing appropriate assessment techniques. This retrospective analysis systematically assessed the effectiveness of orovestibular movements across the entire dentition through 3D superimposition, considering the effects of jaw structure, tooth type,

and the Invisalign® system. Data and clinical models were sourced from a randomly selected patient cohort, without regard to initial malocclusion or the extent of planned tooth correction, to encompass a diverse range of cases, which were categorized into two groups. Group 1 consisted of 18 adult patients treated with the standard Invisalign® system, while Group 2 included 17 adolescent participants treated with Invisalign® Teen. The effectiveness of planned versus clinically achieved movements was analyzed for each tooth, focusing only on those that exhibited planned translations exceeding 0.2 mm and/or planned rotations greater than 2°, as inaccuracies in the digitalization process combined with the proposed method could lead to significant relative discrepancies for minor tooth movements. High to very high effectiveness in achieving translations in both oral and vestibular directions was observed for the lower jaw in adolescents and for adults, with the exception of the lower molars in the latter group. Notably, the efficacy of translational movements was particularly remarkable for the first and second lower premolars, achieving rates of 91–98%. In the upper jaw, successful translational movements were also observed in the anterior and premolar regions, although effectiveness diminished for canines and molars.

28. **Loberto S, Pavoni C, Fanelli S et al (2024)[52]** conducted an evaluation of the predictability of dental expansion in patients undergoing treatment with Clear Aligners (CA) during the early mixed dentition phase. Their analysis focused on the effectiveness of expansion at the conclusion of the initial set of aligners and at the treatment's end, revealing that CA can facilitate substantial transverse increases. However, the predictability of this expansion varied, not surpassing

50% during the first aligner set. To enhance predictability to approximately 70%, a refinement set was necessary. Notably, the predictability of expansion was found to be greater in the lower arch compared to the upper arch.

29. **Li N, Wang C, Yang M, Chen D et al (2024)[53]** conducted the researchers examined the biomechanical implications of various tooth movement patterns and aligner thicknesses on teeth and periodontal tissues during maxillary arch expansion using clear aligners. The aim was to enhance the precision and efficiency of clinical orthodontic treatments. The findings indicated that thicker aligners led to a greater buccal displacement of the crowns and heightened stress on the periodontal ligament. During the maxillary arch expansion with clear aligners, the primary movement observed in the target teeth was a tilting motion. An increase in molar expansion resulted in greater buccal displacement of the first molar, while the buccal displacement of the premolars decreased. Implementing alternating movements of premolars and molars at intervals improved arch expansion efficiency, although careful consideration of the anchorage of adjacent teeth is necessary. While thicker aligners enhance expansion efficiency, they may also impose additional strain on the periodontal tissues.

30. **Lin, Tian, Zhang et al (2024)[54]** aimed to assess the effects of the Invisalign® First System on the dental arch circumference and incisor inclination in patients undergoing mixed dentition. This research involved 21 children, comprising 10 females and 11 males, who were treated with non- extraction methods using clear aligners from the Invisalign® First System, without the addition of any auxiliary devices apart from Invisalign® accessories. The planned arch expansion was set at 0.15 mm for each stage, and no over-correction was intended in the arch

expansion, with the primary objective being the establishment of a cusp-fossa relationship. Post-treatment measurements indicated a significant increase in the width of the first permanent molar, with pre-treatment width recorded at 40.55 ± 2.18 mm and post- treatment width at 43.57 ± 2.09 mm. The intended arch expansion was 4.1 mm (±1.4 mm), while the actual expansion achieved was 3.0 mm (±1.7 mm). Furthermore, the torque expression rate for the upper anterior teeth was noted to be 56.53%. They concluded that the Invisalign® First System clear aligners are effective in expanding the arch circumference in patients during the mixed dentition phase, while also managing incisor torque to rectify malocclusions such as labial and lingual inclinations of incisors, as well as deep overbites.

31. **Qinyi LÜ, Ziqi GA, Qingchen FE et al (2024)[55]** performed a finite element analysis to investigate the direction, efficiency, and mechanical load associated with the displacement of single teeth using clear aligners for expansion treatment during the transitional dentition phase. Furthermore, they developed overcorrection and torque compensation systems to mitigate the issues of inadequate expansion efficiency and the buccal inclination of posterior teeth. The findings indicated that the expansion treatment with clear aligners during the transitional dentition primarily focused on the buccal expansion of teeth, with varying expansion rates observed among different teeth. Specifically, at a designated expansion amount of 0.200 mm per side, the expansion efficiencies recorded were 51.86% for the maxillary first permanent molar, 68.76% for the second primary molar, 73.48% for the first primary molar, and 84.17% for the primary cuspid. The implementation of over-correction (0.275, 0.300, 0.325 mm)

resulted in a notable improvement in the expansion outcomes. They concluded that when the overcorrection length reached 150% (0.300 mm), the expansion efficiencies for the maxillary first permanent molar, second primary molar, first primary molar, and primary cuspid were 75.16%, 99.96%, 107.35%, and 122.37%, respectively, with the expansion efficiencies for the maxillary second primary molar, first primary molar, and primary cuspid approaching 100.00%.

32. **Karslı N, Ocak I, Akyıldız M, Gögen H et al (2024)[56]** conducted study on the impact of various attachment configurations, both with and without buccal root torque, on the expansion movements facilitated by aligners was assessed through finite element analysis. The finite element analysis involved the application of a 0.25 mm buccal expansion force to the maxillary molars, utilizing different attachment configurations. The findings indicated that the use of aligners resulted in both buccal and mesial tipping of the maxillary molars, with an observed increase in buccal tipping from the first to the second molars. The researchers concluded that incorporating occlusally beveled attachments and compensating for buccal torque significantly reduced the occurrence of uncontrolled buccal tipping.

33. **Bruni A, Ferrillo M, Gallo V et al (2024)[57]** conducted a randomized controlled trial to compare the efficacy of clear aligners and rapid palatal expanders (RPEs) in increasing palatal volume and surface area in patients during the mixed dentition phase. This study is significant as it addresses the growing interest in using clear aligners for maxillary expansion in younger patients—a population traditionally managed with fixed expansion appliances. The methodology involved enrolling mixed dentition patients who were randomly assigned to either a clear aligner group or an RPE group. The study included a total of 44

participants**,** randomly assigned into two groups: 22 treated with clear aligners and 22 with RPEs.Pre- and post-treatment intraoral scans were analysed using three-dimensional imaging software to measure changes in palatal volume and surface area. Results indicated that both treatment modalities produced statistically significant increases in palatal dimensions. However, the RPE group achieved a greater increase in both palatal volume and surface area compared to the clear aligner group. Despite this, the clear aligners still demonstrated a capacity for achieving dentoalveolar expansion without the invasiveness or discomfort often associated with RPEs. Bruni et al. concluded that while RPEs remain more effective for achieving skeletal expansion in mixed dentition, clear aligners can be a viable alternative for mild to moderate cases requiring less aggressive transverse development. The study emphasizes the importance of patient selection and treatment goals when considering aligners for early interceptive expansion therapy.

34. **Silvestrini-Biavati F, Imenpour S, Poli F et al (2024)[58]** conducted a three-dimensional case-control study to compare the efficacy of maxillary expansion in the mixed dentition phase using clear aligners and the Leaf Expander. The objective was to analyze and contrast the transverse dentoalveolar effects of both appliances using digital dental models. The study included a total of 40 patients, divided equally into two groups: 20 treated with clear aligners and 20 with the Leaf Expander. All patients were in the mixed dentition stage and underwent digital scanning before and after treatment to evaluate changes in intercanine, interpremolar, and intermolar widths. Results indicated that both groups experienced statistically significant maxillary expansion. However, the Leaf

Expander group exhibited greater skeletal changes, particularly in the posterior region, while the aligner group achieved more dentoalveolar tipping movements with less skeletal effect. The aligners were noted for their esthetic advantage and patient comfort, though their expansion was more limited. They concluded that while clear aligners are effective for mild to moderate dentoalveolar expansion, the Leaf Expander remains more suitable for cases requiring substantial skeletal widening in growing patients. The study emphasizes the importance of selecting the appropriate appliance based on the desired treatment outcomes and the stage of dental development.

35. **Rozzi M, Mucedero M, Fanelli S et al (2024)[59]** conducted a comparative clinical study to evaluate smile aesthetics and outcomes in preadolescent patients treated with two different interceptive orthodontic approaches: traditional therapy using Rapid Maxillary Expansion (RME) combined with a Schwarz plate, and clear aligners. The focus was on assessing which method produced more favourable changes in smile esthetics during early orthodontic intervention. The study included a total of 40 preadolescent patients, divided into two equal groups: 20 patients treated with RME/Schwarz plate and 20 patients treated with clear aligners. Standardized frontal smile photographs were taken before and after treatment and were evaluated by a panel of laypeople and orthodontists using validated esthetic assessment scales. The results indicated that both treatment modalities led to improved smile **e**sthetics, with significant increases in smile width and exposure of maxillary teeth. However, patients treated with clear aligners showed greater improvements in smile symmetry and dental alignment, while those treated with traditional appliances exhibited more pronounced transverse arch development. Rozzi et al. concluded that both approaches are

effective for early orthodontic intervention, but clear aligners offer a more esthetic, patient-friendly alternative for improving smile characteristics. They emphasized the importance of individualized treatment planning, particularly when smile outcomes are a key concern during interceptive therapy.

36. **Kalekar AA, Manchanda J, Chavan S et al. (2024)[60]** conducted a systematic review and meta-analysis to evaluate the effectiveness of maxillary arch expansion using clear aligners in adult patients. The primary aim was to synthesize existing clinical evidence on the extent, predictability, and nature (skeletal vs. dentoalveolar) of expansion achieved through aligner therapy. The review included multiple clinical trials and observational studies, pooling data from a total of 652 adult patients across various study designs. Quantitative analysis focused on changes in intermolar and interpremolar widths, as well as the degree of bodily movement versus buccal tipping. The review also examined the role of attachments, aligner design, and treatment protocols on expansion outcomes. Results indicated that clear aligners are effective in achieving statistically significant maxillary transverse expansion, primarily though dentoalveolar changes such as buccal tipping rather than true skeletal widening. The average expansion was more predictable in the premolar region and tended to be underexpressed in posterior segments, particularly the first molars. They concluded that while clear aligners are a viable option for treating mild to moderate transverse discrepancies in adults, clinicians must account for their limitations in skeletal expansion. Overcorrection in digital planning, proper case selection, and the adjunctive use of attachments can help improve treatment predictability.

37. **Nguyen KV et al. (2024)[61]** evaluated buccal alveolar bone changes in adult patients undergoing non-extraction treatment with clear aligners. The study focused on assessing how dentoalveolar expansion affects buccal bone thickness and height, particularly in adult patients where bone remodeling capacity may be reduced. A total of 30 adult patients were included in the study, all treated with Invisalign® and without any extractions. Pre- and post-treatment cone-beam computed tomography (CBCT) scans were analyzed to measure buccal bone dimensions at the maxillary premolar and molar regions. The results demonstrated that while buccal bone height remained largely stable, there was a statistically significant reduction in buccal bone thickness, especially in the premolar region. This reduction correlated with the extent of transverse expansion programmed into the aligner treatment. Nguyen concluded that clear aligners can produce effective transverse expansion in adults, but may lead to minor reductions in buccal bone thickness. The findings highlight the importance of careful case selection, particularly in patients with thin buccal cortical plates, and underscore the value of CBCT imaging in monitoring periodontal safety during treatment planning.

38. **Rojas GA, García-Melo JI, Aristizábal et al (2024)[62]** conducted a study focusing on the biomechanical effects on periodontal ligaments during maxillary arch expansion using thermoformed clear aligners. Their research employed advanced computational modeling techniques to simulate the force distribution and stress patterns generated by the aligners on the periodontal ligament (PDL) and surrounding structures. Specifically, finite element analysis (FEA) was used to create a detailed 3D model of the maxillary arch, teeth, and periodontal tissues to evaluate the biomechanical responses under different expansion scenarios. The

results demonstrated that thermoformed aligners can generate sufficient and well-distributed forces to achieve maxillary expansion without exceeding the physiological limits of the PDL, minimizing risks of tissue damage. The study also identified critical regions of stress concentration, providing insights into how aligner design can be optimized to promote more efficient and safe tooth movement. Importantly, the computational data suggested that the use of clear aligners for maxillary expansion could be a viable, less invasive alternative to traditional expansion devices, offering better patient comfort and aesthetic benefits. In conclusion, they established that thermoformed aligners are capable of inducing controlled maxillary expansion through biomechanically favorable force application, supported by precise computational modeling.

39. **Kim and So Hee (2024)[63]** compared the forces and moments generated by direct print aligners (DPAs) and thermoformed aligners (TFAs) during maxillary posterior expansion . The research assessed the biomechanical impacts of three different expansion designs—uniform expansion (U4-U7), targeted expansion of U4 and U6, and targeted expansion of U5 and U7—utilizing an in vitro experimental framework. The results reveal considerable biomechanical variability associated with aligner-based maxillary expansion. While DPAs offer enhanced control over the distribution of forces and moments, they exhibit unpredictability in achieving the intended movements. Conversely, TFAs, although capable of generating stronger forces, tend to cause excessive and inconsistent tipping. These results highlight the necessity for additional research aimed at optimizing aligner designs and improving the predictability of maxillary expansion treatments.

40. **CD Bucur SM, Moga RA, Olteanu et al (2025)[64]** conducted a retrospective clinical study evaluating the efficacy of Nuvola® OP clear aligners in achieving maxillary arch expansion in adult patients. This investigation aimed to assess the amount and predictability of transverse expansion in non-growing individuals, an area traditionally considered challenging due to reduced skeletal adaptability in adults. The study included a sample of adult patients who underwent orthodontic treatment exclusively with Nuvola® OP aligners, with pre- and post-treatment digital models analyzed to quantify changes in arch width at various anatomical landmarks (intercanine, interpremolar, and intermolar widths). The results demonstrated statistically significant increases in transverse dimensions at all evaluated levels, indicating that Nuvola® OP aligners were effective in producing maxillary expansion in adult cases. Moreover, the study highlighted a higher degree of expansion in the premolar and molar regions compared to the anterior segment, aligning with the design features of the aligners that apply targeted forces posteriorly. The findings supported the clinical viability of clear aligners in achieving moderate arch expansion without auxiliary appliances or surgical assistance. They concluded that Nuvola® OP clear aligners can successfully produce measurable maxillary expansion in adults, offering a non-invasive alternative to conventional techniques. These outcomes further support the role of modern clear aligner systems in facilitating complex orthodontic movements, including transverse arch development, while maintaining aesthetic and comfort advantages.

41. **Meuli S, Gentile D, Garcovich D et al (2025)[65]** conducted a retrospective study to explore the relationship between transverse and sagittal dimensions in the early

stages of development, comparing patients treated with clear aligners to untreated individuals. The study aimed to determine whether clear aligner therapy influences sagittal parameters, such as overjet and molar relationship, in conjunction with transverse changes during early orthodontic intervention. The study evaluated a total of 100 patients, with 50 treated using clear aligners and 50 untreated controls. Digital dental models were used to assess arch widths and sagittal dental relationships. The primary objective was to assess whether early transverse expansion via aligners had a measurable impact on sagittal dental correction, particularly in growing patients. Findings revealed that patients treated with clear aligners showed statistically significant improvements in both transverse and sagittal dimensions compared to the untreated group. Specifically, transverse expansion achieved through aligners was moderately correlated with favorable sagittal changes, including improved molar and canine relationships. This suggests that transverse development using clear aligners may positively influence overall occlusal relationships in early treatment stages. They concluded that clear aligners can be effective not only in managing transverse deficiencies but also in supporting early sagittal correction when appropriately indicated.

42. **Cengiz SM and Goymen M (2025)[66]** investigated the impact of aligner thickness on the effectiveness of orthodontic tooth movement using clear aligner therapy. The study aimed to determine whether varying aligner material thicknesses influence the efficiency, predictability, and quality of treatment outcomes. The researchers compared clear aligners of different thicknesses—typically categorized as standard and thick—by evaluating clinical outcomes such as tooth movement accuracy, treatment duration, and patient comfort. Quantitative

assessments of tooth displacement were made using digital models, and subjective data on patient experience were collected. The findings revealed that thicker aligners generated slightly more controlled and forceful tooth movement, potentially improving the predictability of certain movements such as rotations and bodily shifts. However, they also resulted in greater discomfort during initial stages. In contrast, standard thickness aligners were better tolerated but showed slightly lower movement precision in complex cases. They concluded that aligner thickness should be carefully considered in treatment planning. A customized approach balancing force efficiency and patient comfort may enhance clinical outcomes, particularly in cases requiring significant movement or anchorage control.

Materials And Method

MATERIALS AND METHOD

STUDY SITE

Department of Orthodontics & Dentofacial Orthopaedics, Santosh Dental college, Santosh Deemed to be University, Ghaziabad.

STUDY DESIGN

This study was designed as a prospective analytical study to evaluate the effectiveness of maxillary expansion using clear aligner therapy by comparing the planned digital outcomes with the clinically achieved results at the end of 16 weeks.

STUDY SUBJECTS

The sample for this study was drawn from the patients with Angle's Class I malocclusion with mild to moderate crowding, who reported to the Department of Orthodontics and Dentofacial Orthopaedics, Santosh Dental College and Hospital, seeking orthodontic treatment.

INCLUSION CRITERIA FOR SELECTION OF STUDY SUBJECTS

- Age between 20 and 30 years old
- Both male and female patients
- Good tooth contour, with sufficient height of clinical crowns
- Mild to moderate crowding (2 to 6 mm)
- Patients with constricted maxillary arch
- Patients with healthy periodontium with good oral hygiene
- Patients with unilateral or bilateral crossbite.
- Patient who gave the informed consent
- Patient who are willing to comply with the treatment protocol, including wearing aligners for 20-22hr/day.

EXCLUSION CRITERIA FOR SELECTION OF STUDY SUBJECTS

- Systemic disease or drug-taking history affecting tooth movement
- Orofacial malformation syndromes;
- Multiple and/or advanced caries
- Signs and/ or symptoms of temporomandibular disorders (TMDs)
- Active periodontal disease
- Patients with poor oral hygiene
- Patients requiring significant transverse expansion beyond predictable limits of aligner therapy
- Patients with skeletal discrepancies requiring orthognathic surgery or fixed orthodontic therapy
- Patients with habits that could interfere with aligner wear (eg bruxism /frequent snacking)
- Excessive dental erosion at the cusp level such that the apex of the dental cusps cannot be found

SAMPLE SIZE

The sample size for this study was determined using G*Power software version 3.1.9.4 (Heinrich Heine University, Düsseldorf, Germany). A priori power analysis was conducted for a one-sample *t*-test to detect a difference from a constant mean. The parameters used for the calculation included an effect size (Cohen's *d*) of 0.8, an alpha error probability (α) of 0.05, and a desired statistical power of 0.82. The analysis yielded a noncentrally parameter (δ) of 2.77, a critical *t*-value of 1.80, with 11 degrees of freedom, and an actual power of approximately 0.83. Based on these inputs, the required total sample size was estimated to be 12 participants.

ARMAMENTARIUM

Following armamentarium was used:-

- Intra-oral scanner (Shinning 3D)
- Asiga 3D Max UV Dental printer
- d -tech 3D Accuprint print resin
- Washing unit and curing unit
- Biostar Thermal Forming Machine
- Erkodur-al Aligner sheet
- Themisto Digital vernier calliper
- Degree Protector Professional stainless steel with 150mm Scale Dail Indicator

Figure 1. Intraoral Scanner

Figure 2. Asiga Max UV Dental printer

Figure 3. d-tech 3D Accuprint Resin

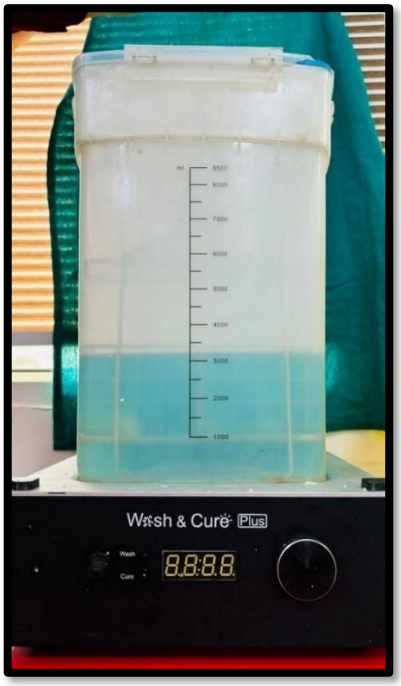


Figure 4. Washing unit

Figure 5. Curing unit

Figure 6. Erkodur-al, Aligner sheet

Figure 7. Scheu Pressure Moulding machine Biostar

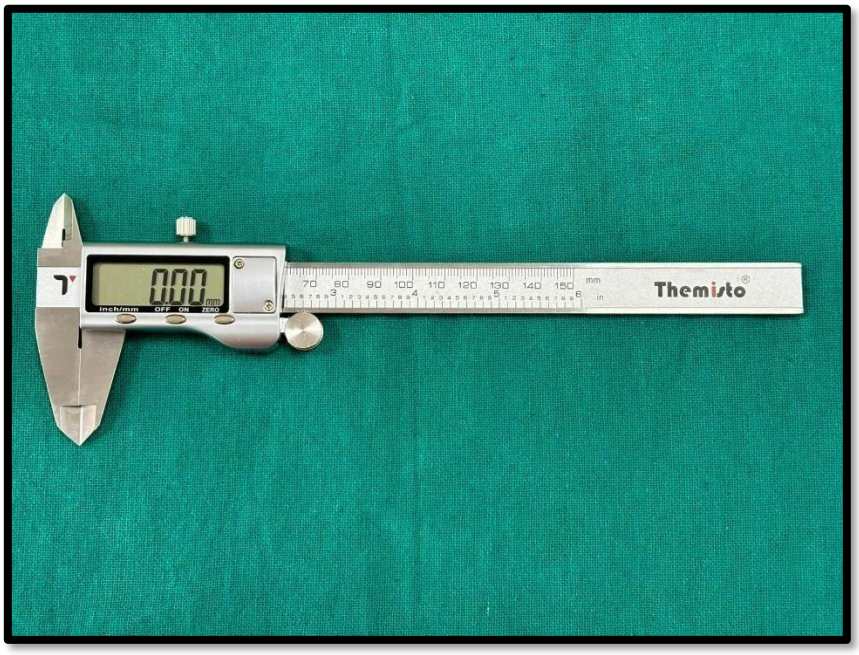


Figure 8. Themisto Digital Vernier caliper

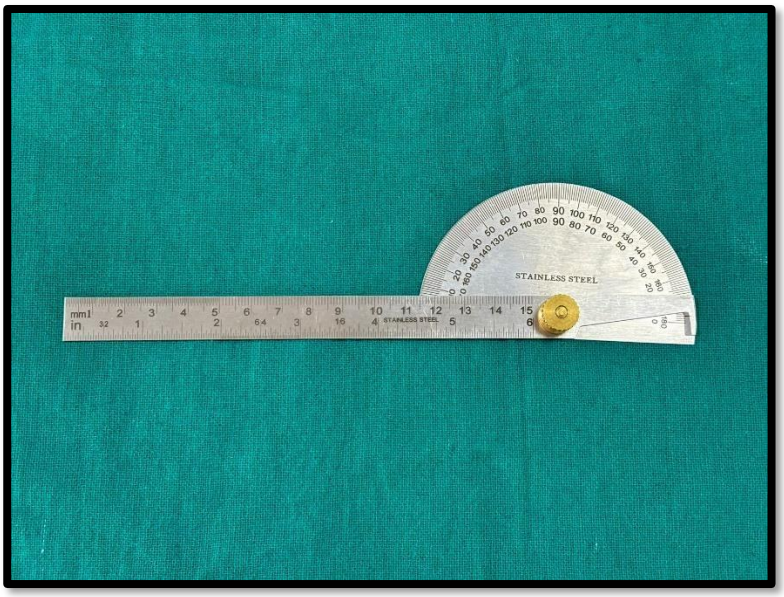


Figure 9. Degree Protector Professional Stainless Steel with 150 mm Scale Dial Indicator

METHODOLOGY

ETHICAL CONSIDERATION

The study was approved by the Institutional Ethics committee of Santosh Deemed to be University (F. No. SU/2023/2480[16]) after presentation of aims, objectives and methodology (Annexure III).

INFORMED CONSENT

Consent form were signed by the patient stating that they have voluntarily registered for the study. (Annexure I)

SUBJECTS

The study group included a sample of 12 subjects (7 females, 5 males) with a mean age of 24 ± 3.9 years. All the participants meeting the criteria for inclusion and exclusion were chosen.

TREATMENT PROTOCOL

Maxillary expansion was digitally planned using 3Shape clear aligner studio software. Patients underwent treatment without any additional expansion devices, and only standard aligner attachments were used. Aligners were worn for 20–22 hours per day. Each aligner was changed every 14days. The fit of aligners and attachments were checked every 14 days. Patient Compliance was also checked every 14 days .

DATA COLLECTION TIME POINTS

Measurements were collected as

- **T1 (Pretreatment):** Prior to the start of aligner therapy, using digital intraoral scans or high-accuracy impressions and 3D nodels were printed.
- **T2p (Planned Expansion):** Based on the expansion planned at the end of 16 weeks, 3D models were printed
- **T2a (Achieved Expansion):** Taken from models printed by rescanning done at the end of 16 weeks

Intra -examiner reliability was evaluated by repeating the measurements on 5 pts two weeks later. The reliability of the measurements was assessed using an inter-class correlation coefficient (ICC).

Measured Parameters:

Following transverse linear measurements will be carried out on the upper arch for each T1, T2p and T2a model

1. Intercanine width (ICW): linear distance between cusp tips of canines
2. First Interpremolar width (IPM1W): linear distance between the buccal cusp tips of first premolars
3. Second Interpremolar width (IPM2W): linear distance between the buccal cusp tips of second premolars
4. Mesial first Intermolar width (IM1MC): linear distance between the mesiobuccal cusp tips of first molars

5. Distal first intermolar width (IM_1DC): linear distance between the distobuccal cusp tips of first molars
6. Mesial second Intermolar width (IM_2MC): linear distance between the mesiobuccal cusp tips of second molars,
7. Distal second Intermolar width (IM_2DC): linear distance between the distobuccal cusp tips of second molars
8. Transpalatal first Intermolar width (TP M_1): linear distance between the groove of the first molars at the mucosa
9. Transpalatal second Intermolar width (TP M_2): linear distance between the groove of the second molars at the mucosa,

Following measurements Inclination parameters were measured

1. Buccolingual inclination of first Premolar of left and right
2. Buccolingual inclination of second Premolars of left and right
3. Buccolingual inclination of first Molars of left and right

The following calculations were done:

- Expansion obtained was calculated by the difference between the post-treatment Measurements with respect to the pretreatment measurements (T2a-T1).
- Planned expansion was calculated by the difference between the planned measurements with respect to the pretreatment measurements (T2p-T1).
- Accuracy of expansion was calculated by the difference between planned expansion with respect to the obtained expansion (T2p-T2a).
- Clinical accuracy (%) was achieved for all measurements, using the equation [(expan-sion obtained/planned expansion) × 100].

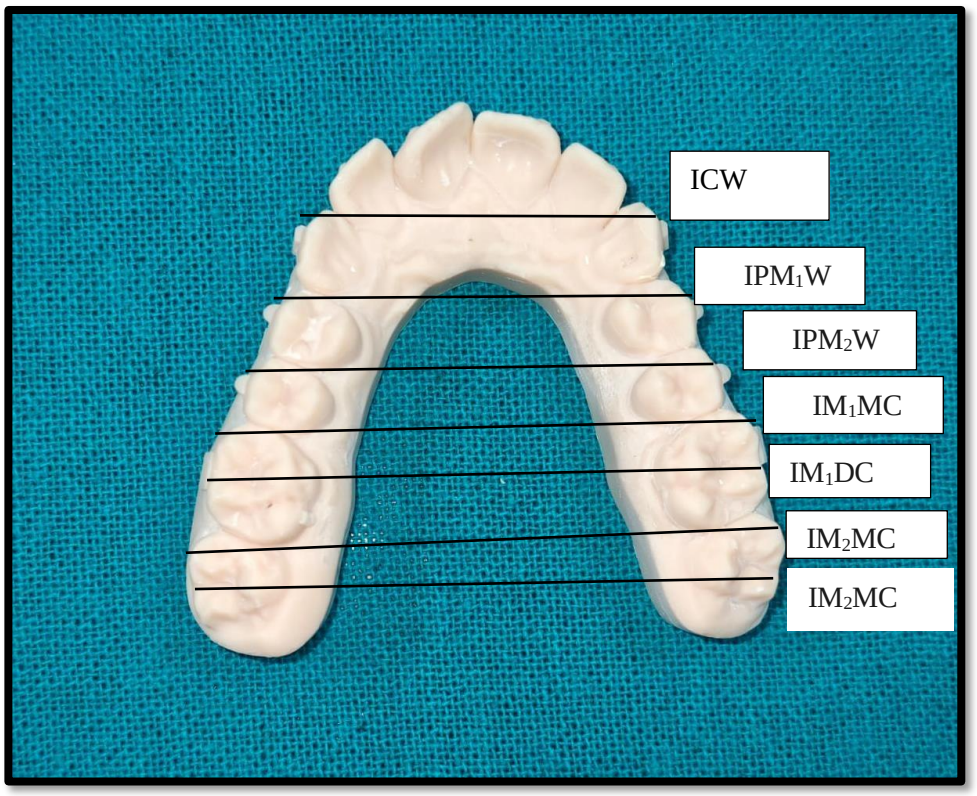


Figure 10a. Linear Parameters

Intercanine width (ICW), First Interpremolar width (IPM1W), Second Interpremolar width (IPM2W), Mesial first Intermolar width (IM1MC), Distal first intermolar width (IM1DC), Mesial second Intermolar width (IM2MC), Distal second Intermolar width (IM2MC)

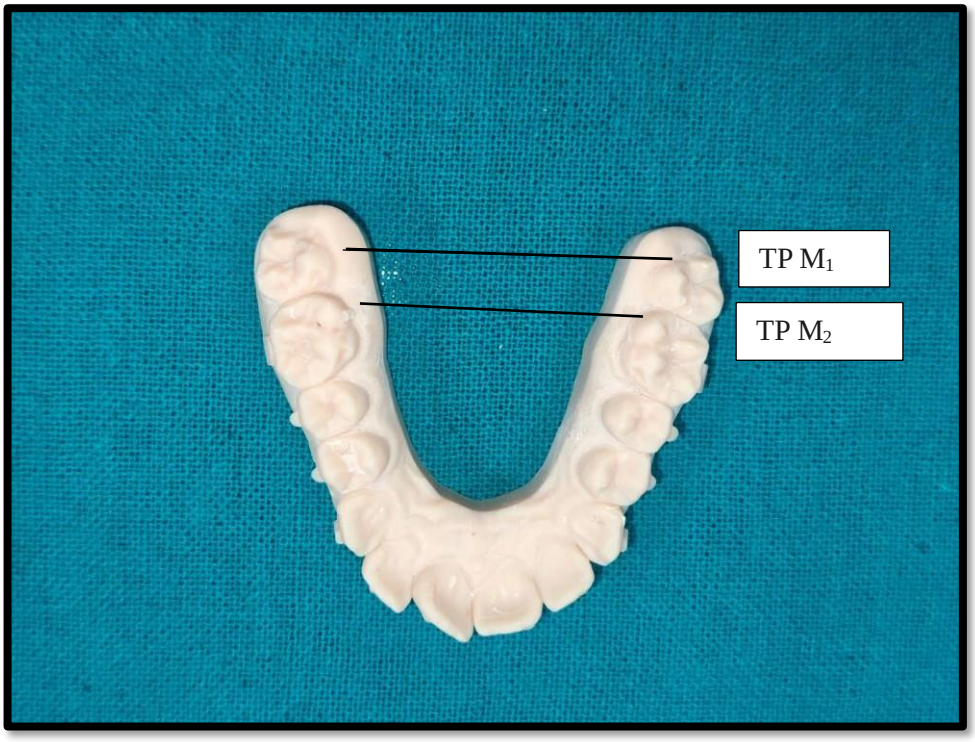


FIgure 10 b. Linear Parameters

Transpalatal first Intermolar width (TP M1), Transpalatal second Intermolar width (TP M2)

Figure 11. Measurement of Intercanine width

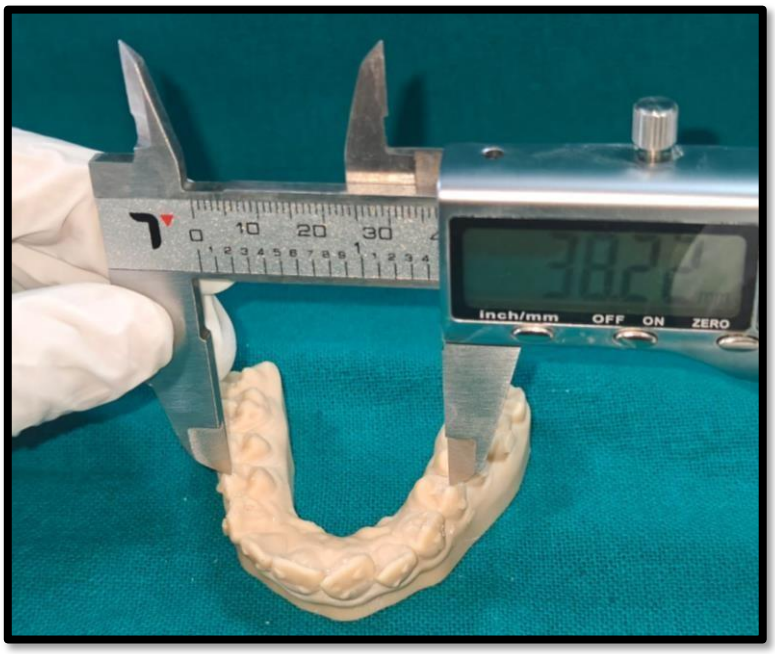


Figure 12. Measurement of First Inter premolar width

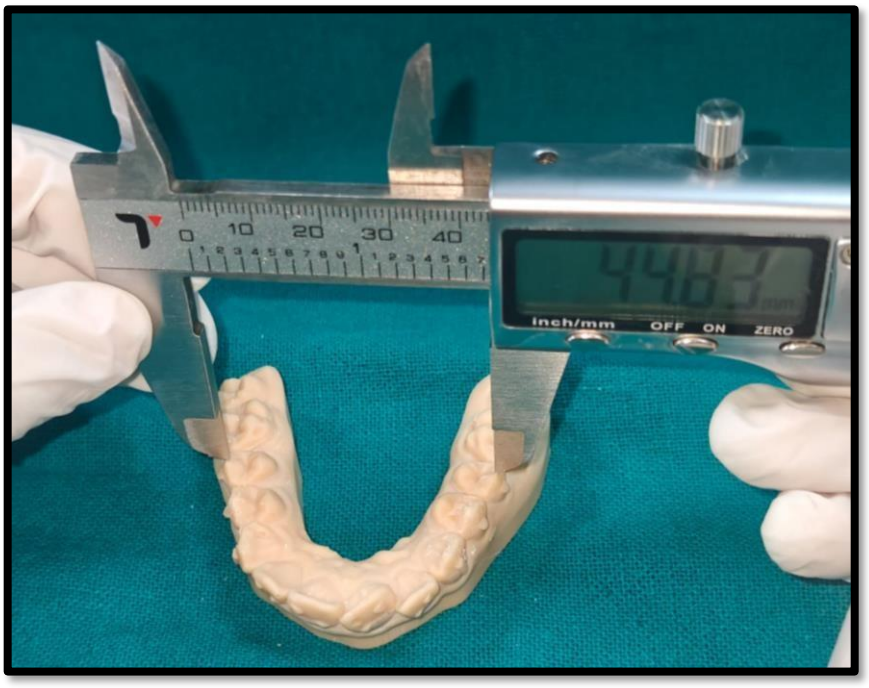


Figure 13. Measurent of Second Inter premolar width

Figure 14. Measurement of Mesial first Intermolar

Figure15. Measurement of Distal first Intermolar width

Figure 16. *Measurement of Transpalatal first molar*

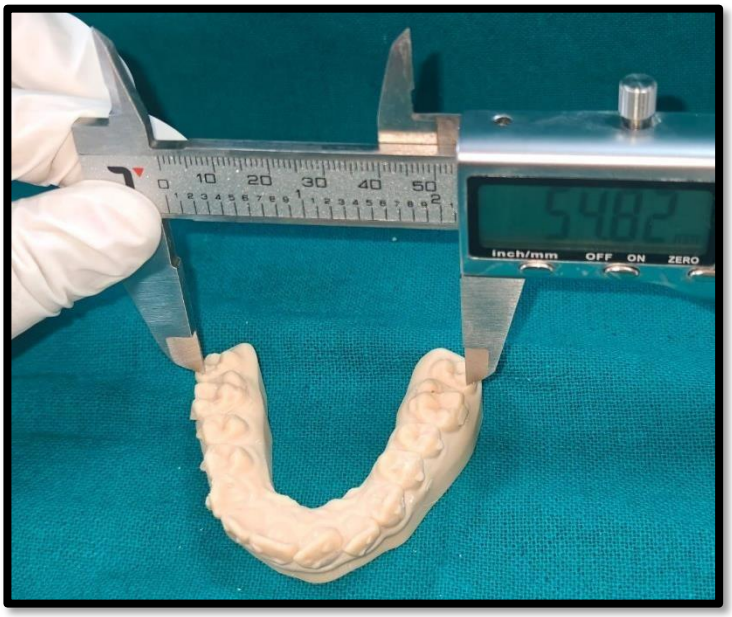


Figure 17. Measurement of Mesial second Intermolar width

Figure 18. Measurement of Distal Second Intermolar width

Figure 19. Measurement of Second Molar Transpalatal

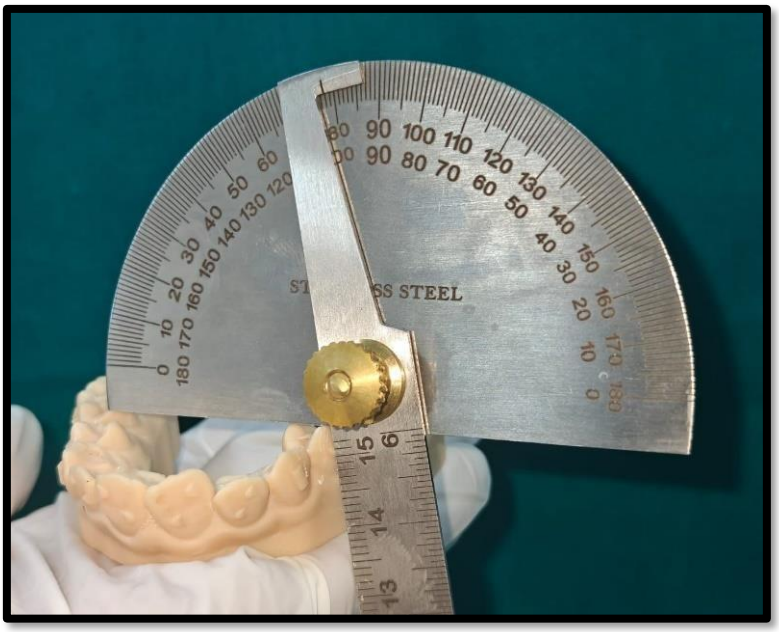


Figure 20. Measurement of Inclination of first premolar (14)

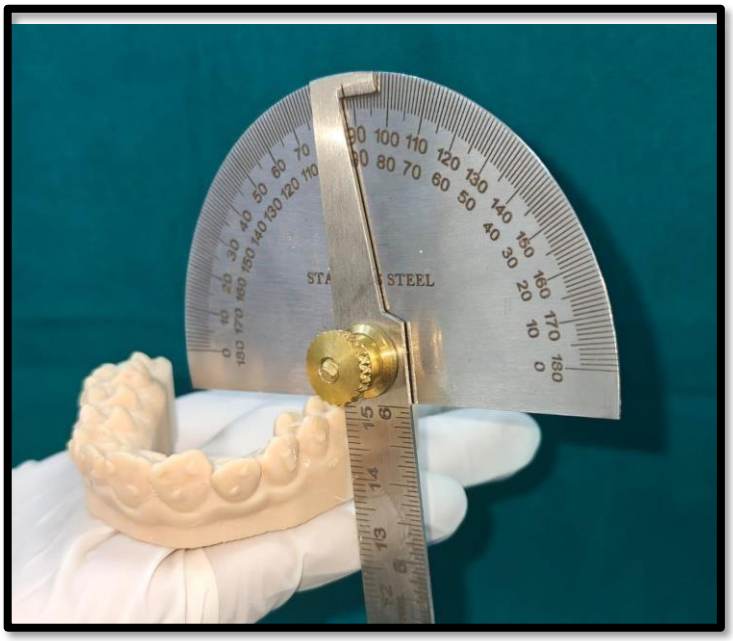


Figure 21. Measurement of Inclination of second premolar (15)

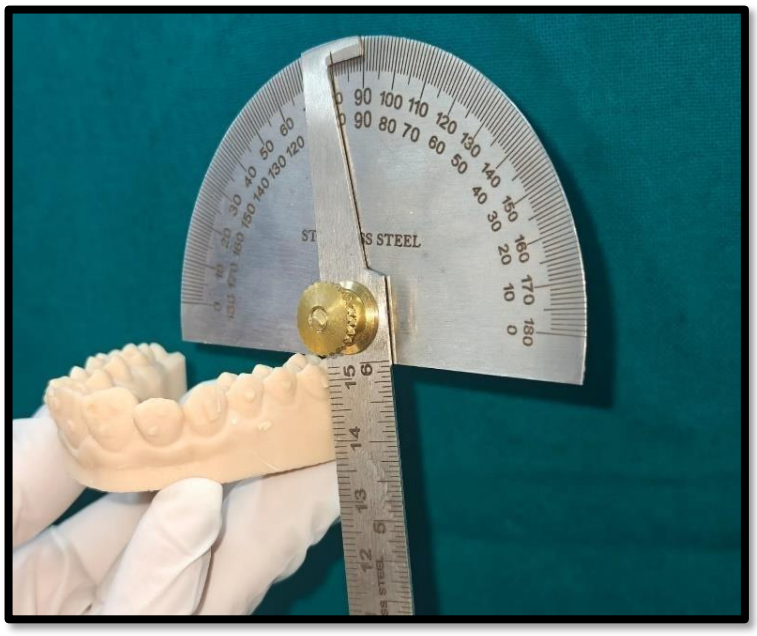


Figure 22. Measurement of Inclination of first molar (16)

Figure 23. Measurement of Inclination of second pre molar (24)

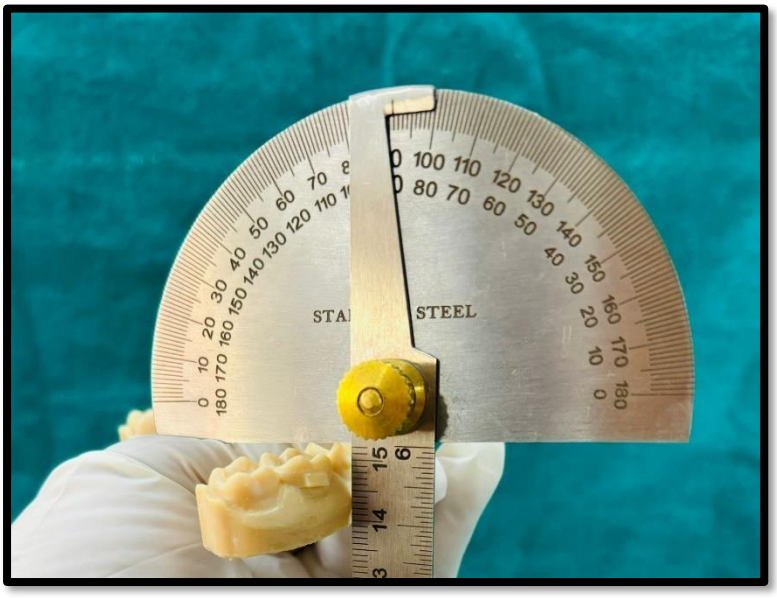


Figure 24. Measurement of Inclination of First premolar (25)

Figure 25. Measurement of Inclination of second premolar(26)

STATISTICAL ANALYSIS

Nine linear factors were used to assess the arch dimension and three angular measurements were recorded to assess changes in the inclination of the teeth. All the parameters were measured on printed models of the maxilla T1, T2a, and T2b. Shapiro-Wilk was done to test the normality of the data. Since the $p>0.05$, the data is normally distributed.

Statistical procedures were carried out in 2 steps:

1. Data compilation and presentation

2. Statistical analysis

Statistical analysis was done using Statistical Package of Social Science (SPSS Version 21.0; Chicago Inc., USA). Data comparison was done by applying specific statistical tests to find out the statistical significance of the comparisons.

Significance level was fixed at $P \leq 0.05$.

Statistical tests employed for the obtained data in our study were: The following Statistical formulas were used:

1. **Mean**: Individual observations were combined together & then divided by the number of observations to obtain the mean. The symbol □ denotes the operation of combining or summarizing.

The individual observation is denoted by the sign X, number of observation denoted by n, & the mean by $\overline{X}$.

$$\overline{X} = \frac{\Sigma X}{\text{No.of observations(n)}} \text{ ,,}$$

2. Standard Deviation: It is denoted by the Greek letter. If a sample is more than 30 then.

$$\sigma = \sqrt{\frac{\Sigma(X-\overline{X})^2}{n}}$$ When sample in less than 30 then,

$$\sigma = \sqrt{\frac{\Sigma(X-\overline{X})^2}{n-1}}$$

3. Paired t test

A paired t test was used to compare the means of two related groups of observations. and their components between the groups. It tests the significance of difference between the means of measurements taken under different conditions in the same subjects. Assumptions in paired t test are that the data must consist of pairs of observations for same subjects, which is normally distributed and the difference between the pairs should be independent of each other.

Formula

$t = x_{diff} / (s_{diff}/\sqrt{n})$ where:

- x_{diff}: sample mean of the differences
- s: sample standard deviation of the differences
- n: sample size (i.e. number of pairs)

4. Independent t test:

It is used to compare the means of two independent groups. Assumptions in independent t test are that the variances of the dependent variable should be approximately equal in both groups, the dependent variable should be normally distributed and the observations within each group must be independent of each other.

Formula

$$t = \frac{(\overline{x_1} - \overline{x_2}) - (\mu_1 - \mu_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Where:

$\bar{X}1$ is mean of first sample, **$\bar{X}2$** is mean of second sample, **μ1** is the mean of first population, **μ2** is the mean of second population, **s1** is the standard deviation of first sample, **s2** is the standard deviation of second sample, **n1** is the size of the first sample, **n2** is the size of the second sample.

p value denotes level of significance:

p > 0.05 Not significant

p ≤ 0.05 Significant (significant at 95% confidence level)

p < 0.01HighlySignificant(significantat99%confidencelevel)

p < 0.000 Very Highly significant (significant at 99.9% confidence level) In aligner therapy,

5. Efficiency = (Achieved expansion / Planned expansion) * 100

This ratio expressed as percentage indicated how closely the treatment outcome matches the initial plan.

6. Interclass correlation coefficient (ICC)

It is a statistical measure that assesses the consistency or agreement between different groups or classes of data. Its often used to evaluate the reliability of measurements, ensuring that different raters or measurements are consistent.

Interpretation of ICC (According to NIH)

- Poor: <0.5
- Moderate: 0.5 to 0.75
- Good: 0.75 to 0.9
- Excellent > 0.9

Results

RESULTS

Table 1. Test of Normality

	Shapiro-Wilk		
	Statistic	df	Sig.
Canine ICW	.978	36	0.675
1st Premolar IPM1W	.907	36	0.105
2nd Premolar IPM2W	.968	36	0.383
1st Molar Mesial Cusp IM1MC	.979	36	0.714
1st Molar Distal Cusp IM1DC	.967	36	0.349
1st Molar trans palatal TP M1	.974	36	0.559
2nd Molar Mesial Cusp IM2MC	.964	36	0.282
2nd Molar Distal Cusp IM2DC	.977	36	0.654
2nd Molar trans palatal TP M2	.974	36	0.542

All variables showed non-significant p-values ($p > 0.05$) in and Shapiro–Wilk test, indicating that the data were normally distributed from table 1.

Table 2. Interclass Correlation coefficient

		N	Interclass Correlation	95% Confidence Interval	
				Lower Bound	Upper Bound
Canine ICMW	T1	5	1.000	.998	1.000
	T2p	5	0.999	.993	1.000
	T2a	5	0.999	.990	1.000
1st Premolar IPM1W	T1	5	0.996	.970	1.000
	T2p	5	1.000	.999	1.000
	T2a	5	1.000	-	-
2nd Premolar IPM2W	T1	5	0.997	.967	1.000
	T2p	5	0.999	.996	1.000
	T2a	5	1.000	-	-
1st Molar Mesial Cusp IM1MC	T1	5	0.998	.985	1.000
	T2p	5	0.995	.957	.999
	T2a	5	0.990	.927	.999
1st Molar Distal Cusp IM1DC	T1	5	0.999	.992	1.000
	T2p	5	1.000	-	-
	T2a	5	1.000	-	-
1st Molar trans palatal TP M1	T1	5	0.980	.864	.998
	T2p	5	1.000	-	-
	T2a	5	1.000	-	-
2nd Molar Mesial Cusp IM2MC	T1	5	1.000	-	-
	T2p	5	0.999	.996	1.000
	T2a	5	1.000	-	-
2nd Molar Distal Cusp IM2DC	T1	5	1.000	-	-
	T2p	5	0.994	.957	.999
	T2a	5	1.000	-	-
2nd Molar trans palatal TPM2	T1	5	1.000	-	-
	T2p	5	0.999	.994	1.000
	T2a	5	1.000	-	-

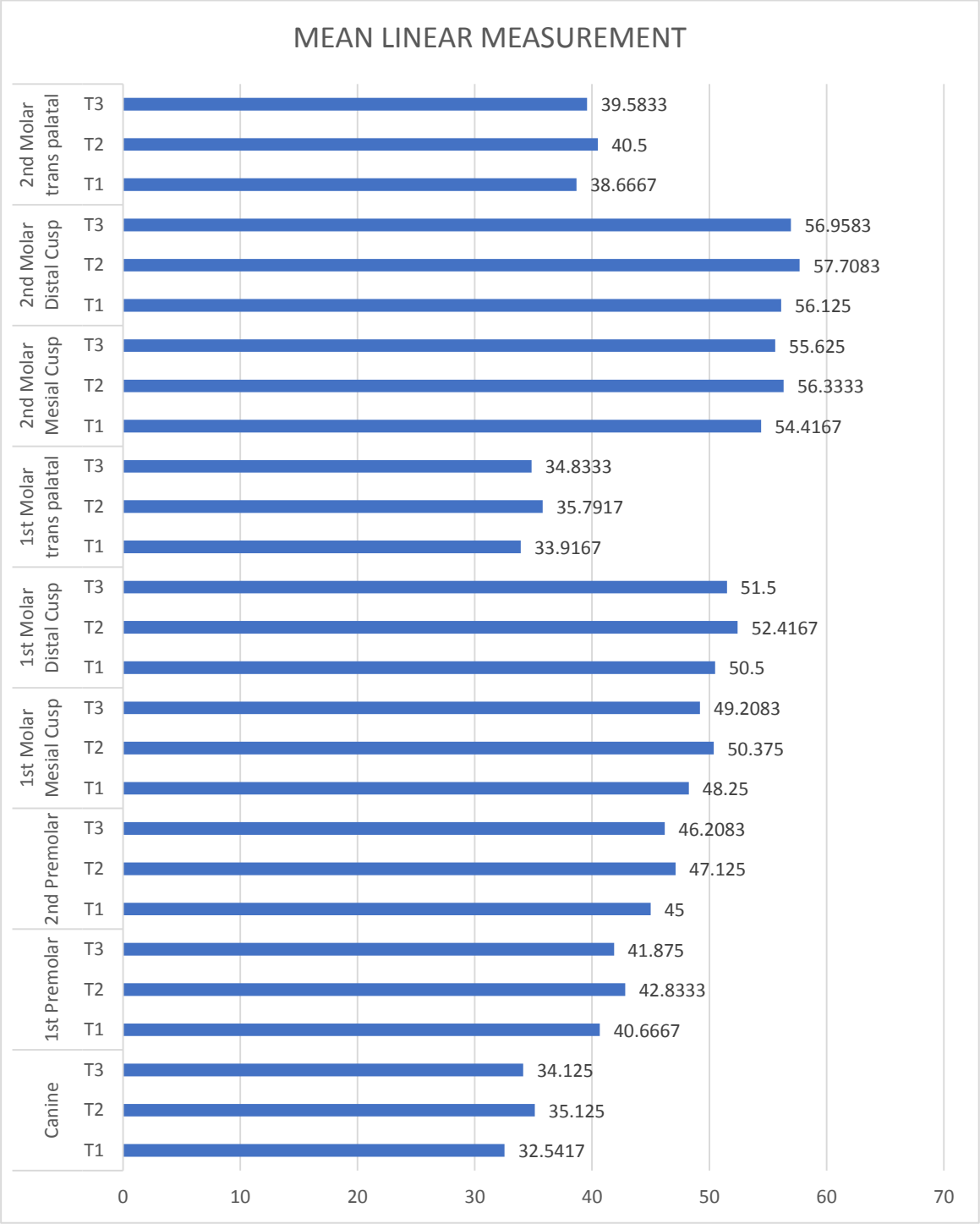
Interpretation of ICC

The intra-examiner reliability for all measurements is excellent, with ICC values consistently above 0.98. This indicates a high degree of consistency and reproducibility in the measurement from table 2.

Table 3. Descriptive Data of Linear transverse Measurement at T1, T2p and T2a

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		p-value
						Lower Bound	Upper Bound	
Canine ICMW	T1	12	32.5417	3.20127	.92413	30.5077	34.5757	0.142
	T2p	12	35.1250	3.06093	.88362	33.1802	37.0698	
	T2a	12	34.1250	3.14877	.90897	32.1244	36.1256	
1st Premolar IPM1W	T1	12	40.6667	3.05505	.88192	38.7256	42.6078	0.254
	T2p	12	42.8333	3.20747	.92592	40.7954	44.8713	
	T2a	12	41.8750	3.17035	.91520	39.8607	43.8893	
2nd Premolar IPM2W	T1	12	45.0000	2.55841	.73855	43.3745	46.6255	0.119
	T2p	12	47.1250	2.43203	.70207	45.5798	48.6702	
	T2a	12	46.2083	2.35930	.68107	44.7093	47.7074	
1st Molar Mesial Cusp IM1MC	T1	12	48.2500	2.14794	.62006	46.8853	49.6147	0.057
	T2p	12	50.3750	1.99003	.57447	49.1106	51.6394	
	T2a	12	49.2083	2.11551	.61069	47.8642	50.5525	
1st Molar Distal Cusp IM1DC	T1	12	50.5000	2.32575	.67138	49.0223	51.9777	0.110
	T2p	12	52.4167	2.22418	.64207	51.0035	53.8298	
	T2a	12	51.5000	1.91881	.55391	50.2808	52.7192	
1st Molar trans palatal TP M1	T1	12	33.9167	2.15146	.62107	32.5497	35.2836	0.119
	T2p	12	35.7917	2.25084	.64976	34.3616	37.2218	
	T2a	12	34.8333	2.05971	.59459	33.5247	36.1420	
2nd Molar Mesial Cusp IM2MC	T1	12	54.4167	3.23218	.93305	52.3630	56.4703	0.351
	T2p	12	56.3333	3.22866	.93203	54.2819	58.3847	
	T2a	12	55.6250	3.22719	.93161	53.5745	57.6755	
2nd Molar Distal Cusp IM2DC	T1	12	56.1250	2.62960	.75910	54.4542	57.7958	0.370
	T2p	12	57.7083	2.76716	.79881	55.9502	59.4665	
	T2a	12	56.9583	2.73411	.78927	55.2212	58.6955	
2nd Molar trans palatal TPM2	T1	12	38.6667	2.38683	.68902	37.1501	40.1832	0.207
	T2p	12	40.5000	2.58492	.74620	38.8576	42.1424	
	T2a	12	39.5833	2.42930	.70128	38.0398	41.1268	

Graph 1. Descriptive Data of Linear transverse Measurement at T1, T2p and T2a



Based on the data from Table 3, Graph 1 although there was an observable increase in transverse dental dimensions from pre-treatment (T1) to the planned expansion (T2p), the actual expansion achieved (T2a) consistently fell short of the planned values across all measured points. Specifically:

- For intercanine width, the planned expansion was 1.64 mm, whereas the achieved expansion was only 0.65 mm.
- At the first premolar region, 1.92 mm of expansion was planned, but only 1.04 mm was achieved.
- At the second premolars, the planned expansion was 2.16 mm, with an achieved expansion of 1.13 mm.
- At the first molar mesial cusps, 2.05 mm was planned, and 1.19 mm was achieved.
- The second molar region had the largest planned expansion of 2.20 mm, but only 1.27 mm was clinically achieved.

In all regions, the actual expansion (T2a) was significantly less than the planned expansion (T2p), indicating underexpression of the intended movements. Despite the directionally correct expansion trend, none of these differences reached statistical significance ($p > 0.05$), though the first molar region approached significance with a p-value of 0.057. This suggests a consistent pattern of underachievement of planned transverse changes, reinforcing the need for overcorrection in digital planning to improve clinical predictability.

Table 4. Paired comparison of linear transverse measurement T1 and T2p

	T1	T2p	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		p-value
						Lower Bound	Upper Bound	
Canine ICW	32.5417	35.1250	-2.58333	.82112	.23704	-3.10505	-2.06162	<0.001*
1st Premolar IPM1W	40.6667	42.8333	-2.16667	.80716	.23301	-2.67951	-1.65382	<0.001*
2nd Premolar IPM2W	45.0000	47.1250	-2.12500	.43301	.12500	-2.40012	-1.84988	<0.001*
1st Molar Mesial Cusp IM1MC	48.2500	50.3750	-2.12500	.71111	.20528	-2.57682	-1.67318	<0.001*
1st Molar Distal Cusp IM1DC	50.5000	52.4167	-1.91667	.76376	.22048	-2.40194	-1.43140	<0.001*
1st Molar trans palatal TP M1	33.9167	35.7917	-1.87500	.85613	.24714	-2.41896	-1.33104	<0.001*
2nd Molar Mesial Cusp IM2MC	54.4167	56.3333	-1.91667	.51493	.14865	-2.24384	-1.58950	<0.001*
2nd Molar Distal Cusp IM2DC	56.1250	57.7083	-1.58333	.46872	.13531	-1.88114	-1.28552	<0.001*
2nd Molar trans palata TPM2	38.6667	40.5000	-1.83333	.61546	.17767	-2.22438	-1.44229	<0.001*

Graph 2. Paired comparison of linear transverse measurement T1 and T2p

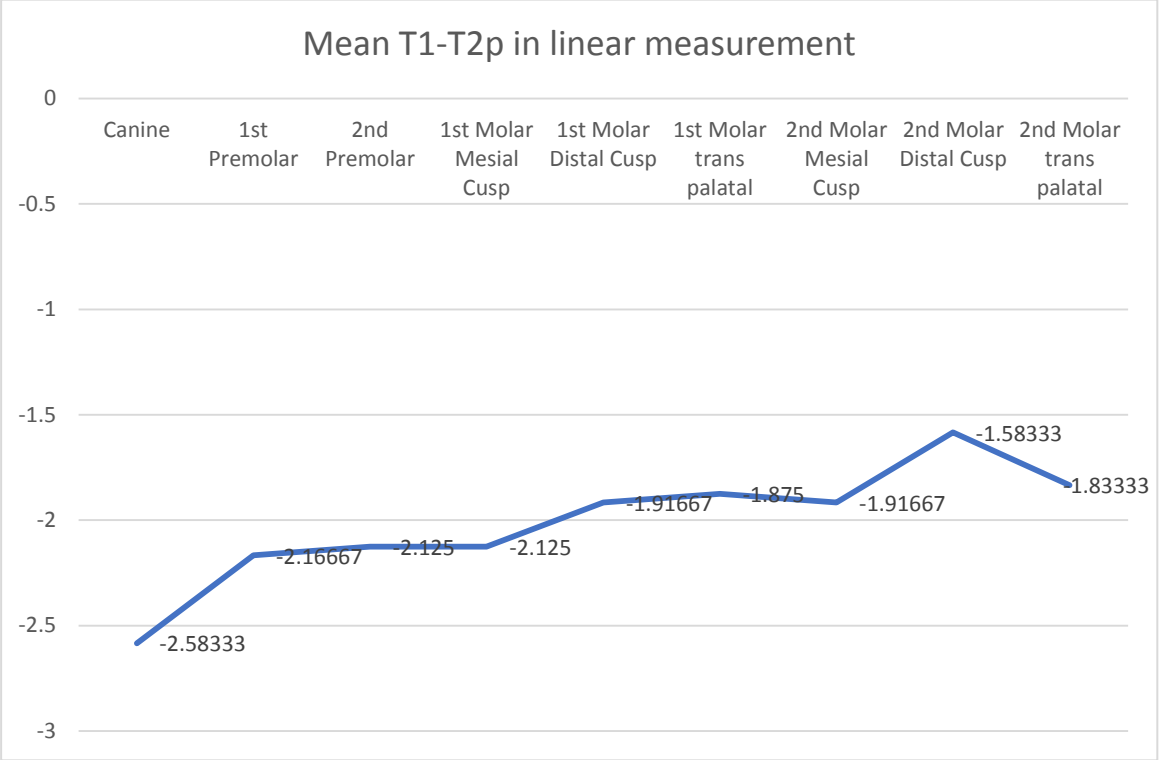


Table 4, Graph 3 shows statistically significant increases in all measured regions, indicating that the planned expansion was greater than the initial (pre-treatment) state. All differences were highly significant ($p < 0.001$).

Table 5. Paired comparison of linear transverse measurement at T1 and T2a

	T1	T2a	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		p-value
						Lower Bound	Upper Bound	
Canine ICW	32.5417	34.1250	-1.58333	.76376	.22048	-2.06860	-1.09806	<0.001*
1st Premolar IPM1W	40.6667	41.8750	-1.20833	.86493	.24968	-1.75788	-.65878	0.001*
2nd Premolar IPM2W	45.0000	46.2083	-1.20833	.54181	.15641	-1.55258	-.86408	<0.001*
1st Molar Mesial Cusp IM1MC	48.2500	49.2083	-.95833	.75252	.21723	-1.43646	-.48020	0.001*
1st Molar Distal Cusp IM1DC	50.5000	51.5000	-1.00000	1.06600	.30773	-1.67731	-.32269	0.008*
1st Molar trans palatal TP M1	33.9167	34.8333	-.91667	.73340	.21171	-1.38265	-.45069	0.001*
2nd Molar Mesial Cusp IM2MC	54.4167	55.6250	-1.20833	.49810	.14379	-1.52481	-.89185	<0.001*
2nd Molar Distal Cusp IM2DC	56.1250	56.9583	-.83333	.68534	.19784	-1.26878	-.39789	0.001*
2nd Molar trans palatal TP M2	38.6667	39.5833	-.91667	.73340	.21171	-1.38265	-.45069	0.001*

Graph 3. Paired comparison of linear transverse measurement at T1 and T2a

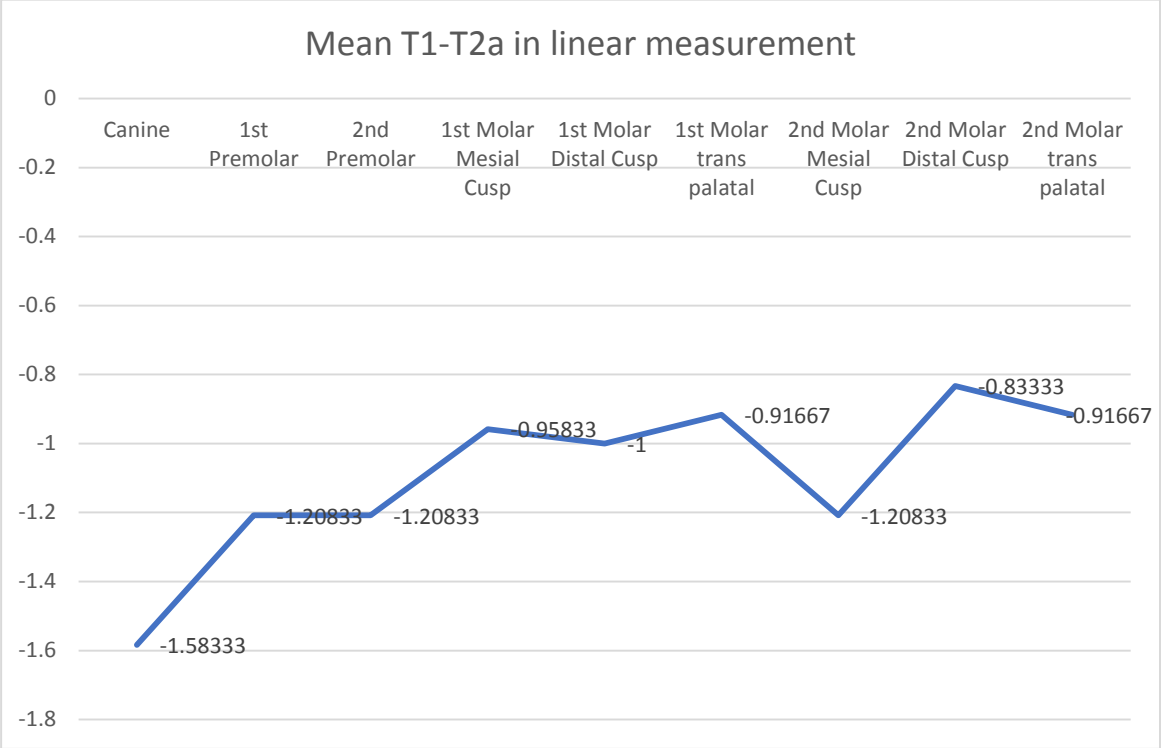


Table 5, Graph 3 showed statistically significant reductions in the achieved measurements compared to the planned values in all measured regions ($p < 0.01$), indicating that the full extent of planned expansion was not realized clinically.

Table 6. Paired comparison of linear transverse measurement at T2p and T2a

	T2p	T2a	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		p-value	Percentage of Accuracy of change
						Lower Bound	Upper Bound		
Canine ICW	35.1250	34.1250	1.00000	.21320	.06155	.86454	1.13546	<0.001*	61.29
1st Premolar IPM1W	42.8333	41.8750	.95833	.25746	.07432	.79475	1.12192	<0.001*	55.76
2nd Premolar IPM2W	47.1250	46.2083	.91667	.35887	.10360	.68865	1.14468	<0.001*	56.86
1st Molar Mesial Cusp IM1MC	50.3750	49.2083	1.16667	.44381	.12812	.88468	1.44865	<0.001*	45.09
1st Molar Distal Cusp IM1DC	52.4167	51.5000	.91667	.63365	.18292	.51406	1.31927	<0.001*	52.17
1st Molar trans palatal TP M1	35.7917	34.8333	.95833	.65569	.18928	.54173	1.37494	<0.001*	48.88
2nd Molar Mesial Cusp IM2MC	56.3333	55.6250	.70833	.68948	.19903	.27026	1.14641	0.004*	63.04
2nd Molar Distal Cusp IM2DC	57.7083	56.9583	.75000	.89188	.25746	.18332	1.31668	0.014*	52.63
2nd Molar trans palatal TP M2	40.5000	39.5833	.91667	.41742	.12050	.65145	1.18188	<0.001*	50.00

.

Graph 4. Paired comparison of linear transverse measurement at T2p and T2a

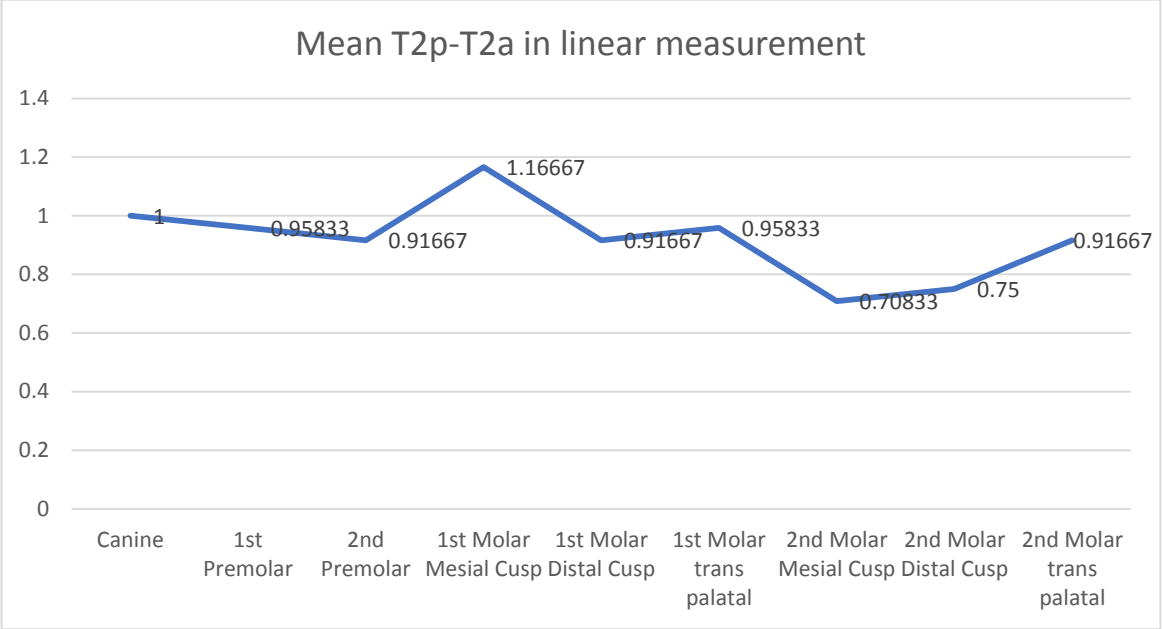
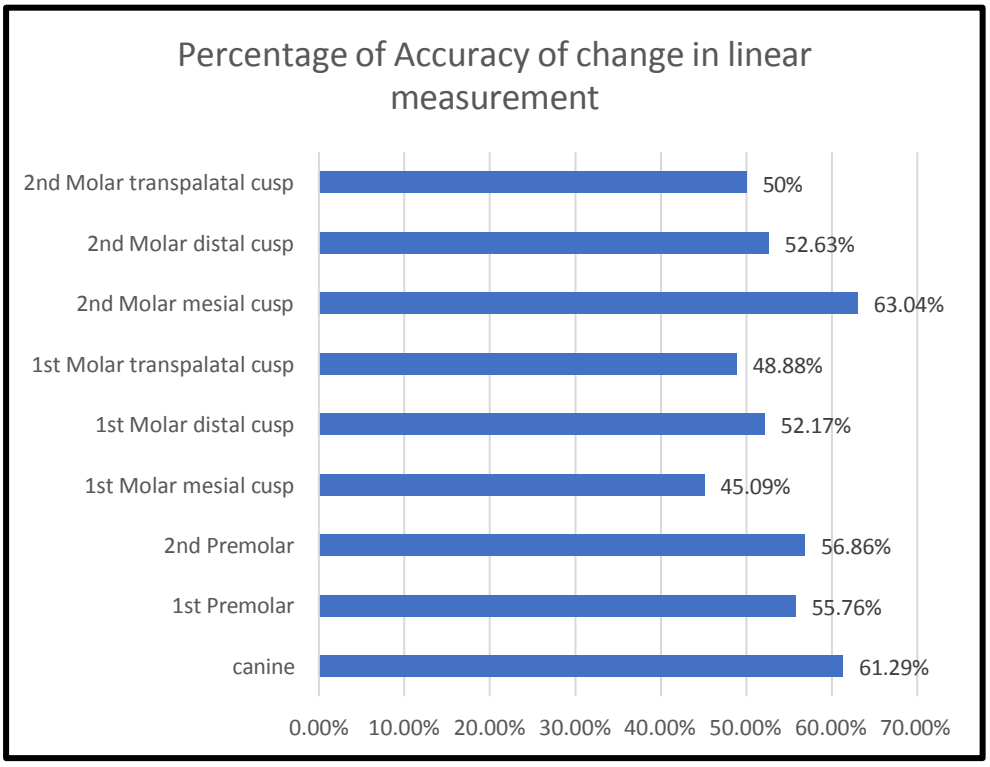


Table 6 , Graph 4 shows statistically significant differences across all measured teeth. The achieved expansion was consistently less than the planned expansion in canines, premolars, and molars. The greatest discrepancies were observed in the first molars, particularly at the mesial cusp, with a mean difference of approximately 1.17 mm. Despite successful expansion overall, these results demonstrate that the final achieved expansion did not fully meet the planned targets, highlighting a clinically relevant difference between expected and actual treatment outcomes.

Graph 5- Percentage of Accuracy of change in linear transverse measurement



There was a statistically significant difference ($p < 0.05$) between the planned and achieved expansion at all measurement points, indicating that clinical expansion (T2a) consistently underperformed compared to the digital plan (T2p**)**.

The canine region showed the highest mean difference (1.00 mm), with a 61.29% accuracy, indicating that only 61% of the planned expansion was expressed clinically.

The first premolar and second premolar regions had mean differences of 0.96 mm and 0.92 mm, respectively, with accuracy percentages of 55.76% and 56.86%, reflecting moderate expression.

At the first molar mesial cusp, the greatest discrepancy (1.17 mm) was recorded, with the lowest accuracy of 45.09%, suggesting a significant underachievement.

The first molar distal cusp and transpalatal width also exhibited notable underexpression, with accuracy levels of 52.17% and 48.88%, respectively.

The second molar mesial cusp had the highest accuracy (63.04%) among all regions, though the absolute difference remained significant (0.71 mm).

Both the second molar distal cusp and transpalatal width had mean differences around 0.75–0.92 mm, with accuracy percentages of 52.63% and 50.00%, respectively.

In summary, while clear aligner therapy achieved statistically significant transverse expansion at all evaluated sites, the clinical outcomes were consistently lower than the planned digital values, with accuracy ranging from 45% to 63%, highlighting the need for overcorrection during digital treatment planning to compensate for the underexpression in real-world outcomes.

Table 7. Descriptive data of Inclination at T1, T2p and T2a

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
14	T1	12	83.1667	3.32575	.96006	81.0536	85.2797
	T2	12	84.4167	3.41010	.98441	82.2500	86.5833
	T3	12	83.9167	3.14667	.90836	81.9174	85.9160
15	T1	12	80.2083	2.06109	.59499	78.8988	81.5179
	T2	12	80.5833	2.85110	.82304	78.7718	82.3948
	T3	12	80.9583	2.36891	.68385	79.4532	82.4635
16	T1	12	76.4167	4.38403	1.26556	73.6312	79.2021
	T2	12	77.7917	4.26113	1.23008	75.0843	80.4991
	T3	12	75.7083	3.06341	.88433	73.7619	77.6547
24	T1	12	80.5417	3.97411	1.14723	78.0166	83.0667
	T2	12	80.7500	4.33013	1.25000	77.9988	83.5012
	T3	12	81.5833	3.86613	1.11606	79.1269	84.0398
25	T1	12	77.3333	3.62650	1.04688	75.0292	79.6375
	T2	12	78.8333	3.52480	1.01752	76.5938	81.0729
	T3	12	78.9167	3.57919	1.03322	76.6426	81.1908
26	T1	12	76.2500	4.65393	1.34347	73.2930	79.2070
	T2	12	78.1250	4.69102	1.35418	75.1445	81.1055
	T3	12	71.6250	22.88223	6.60553	57.0863	86.1637

Graph 6. Descriptive data of Inclination at T1, T2p and T2a

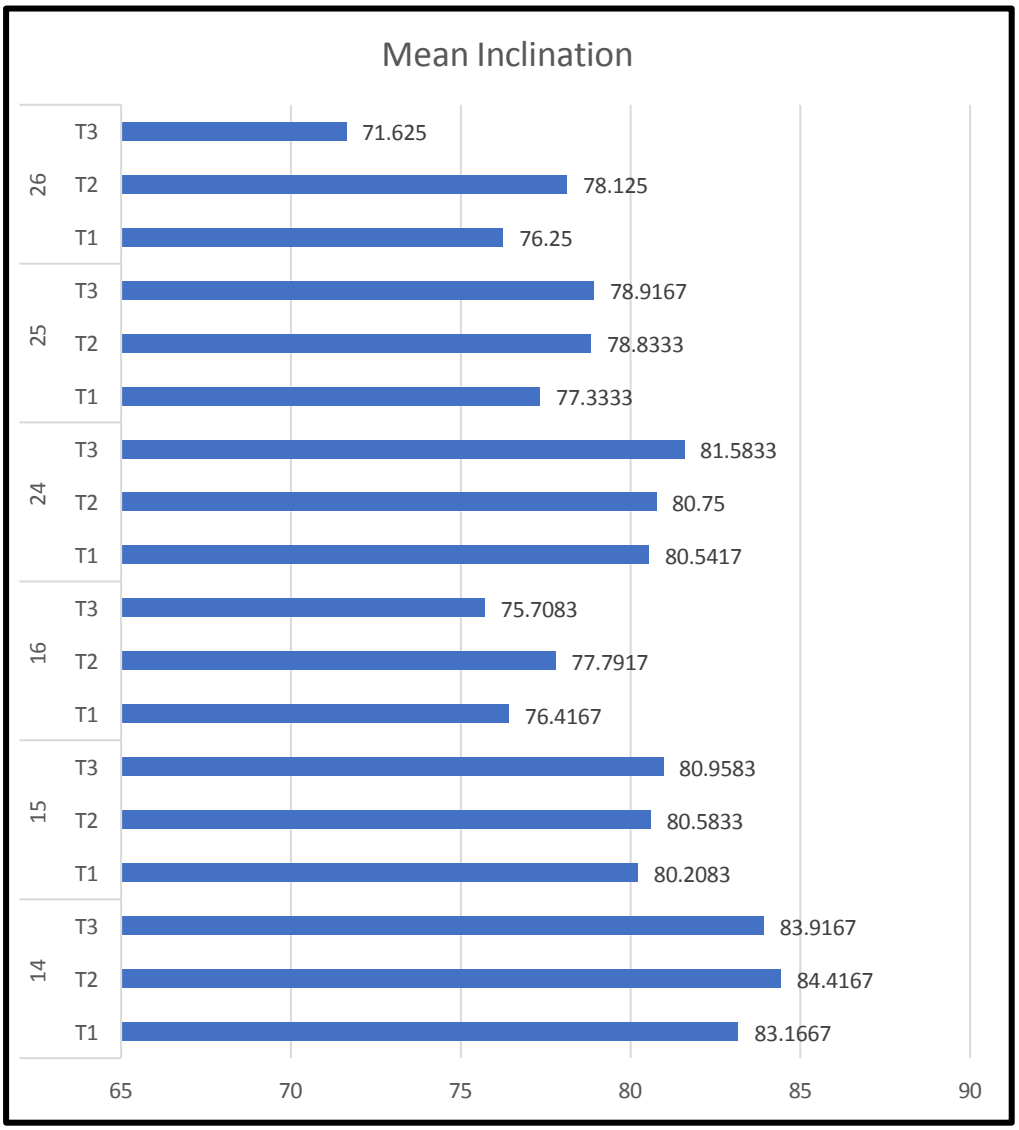


Table 8. Paired Comparison of Inclination at T1 and T2p

	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		p-value
				Lower Bound	Upper Bound	
14	-1.25000	.96531	.27866	-1.86333	-.63667	0.001*
15	-.37500	1.68044	.48510	-1.44270	.69270	0.456
16	-1.37500	.85613	.24714	-1.91896	-.83104	<0.001*
24	-.20833	1.58771	.45833	-1.21712	.80045	0.658
25	-1.50000	1.34840	.38925	-2.35673	-.64327	0.003*
26	-1.87500	1.17018	.33780	-2.61850	-1.13150	<0.001*

Graph 7. Paired Comparison of Inclination at T1 and T2p

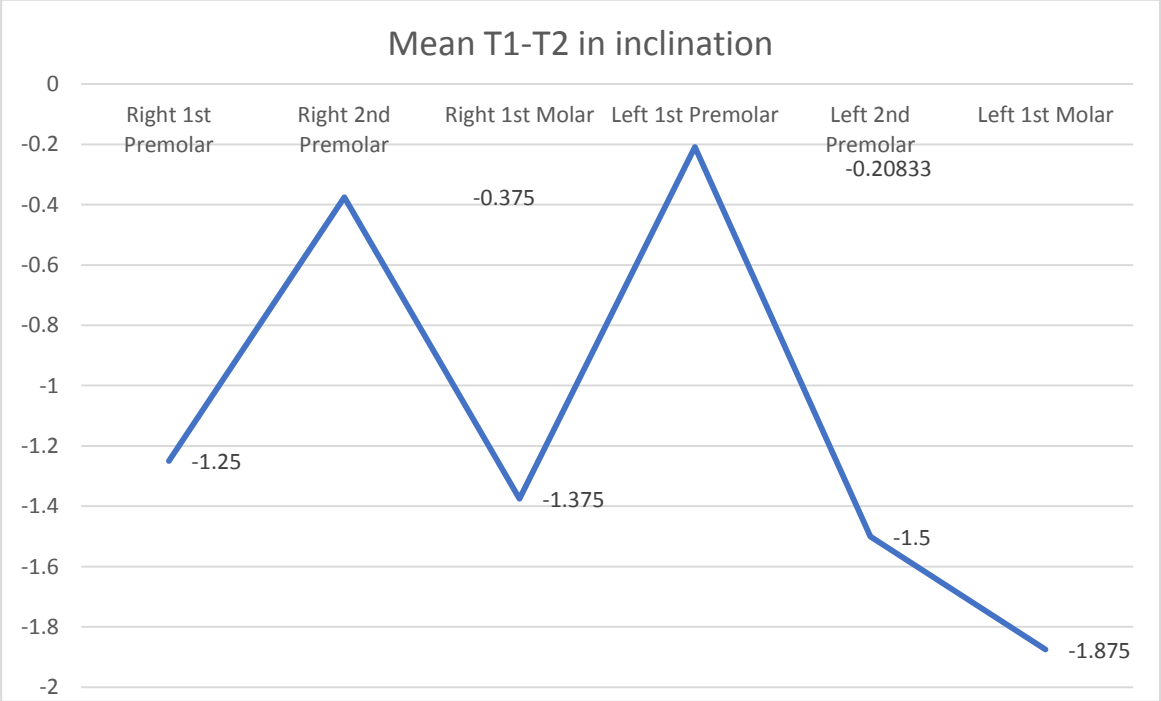


Table 8 ,Graph 7Statistically significant differences were observed for teeth 14, 16, 25, and 26, indicating that the final tooth inclinations deviated meaningfully from the treatment plan ($p < 0.05$). Teeth 15 and 24 did not show significant differences, suggesting closer alignment with the planned treatment.itial (pre-treatment) state. All differences were highly significant ($p < 0.001$). The variation in statistical significance among different teeth underlines the individualized nature of aligner-based treatment planning.

Table 9. Paired Comparison of Inclination at T1 and T2a

	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		p-value
				Lower Bound	Upper Bound	
14	.50000	.60302	.17408	.11686	.88314	0.015
15	-.37500	1.65317	.47723	-1.42537	.67537	0.449
16	2.08333	4.21487	1.21673	-.59467	4.76134	0.115
24	-.83333	2.27969	.65809	-2.28178	.61511	0.232
25	-.08333	2.39159	.69039	-1.60288	1.43621	0.906
26	6.50000	20.33582	5.87044	-6.42076	19.42076	0.292

Graph 8. Paired Comparison of Inclination at T1 and T2a

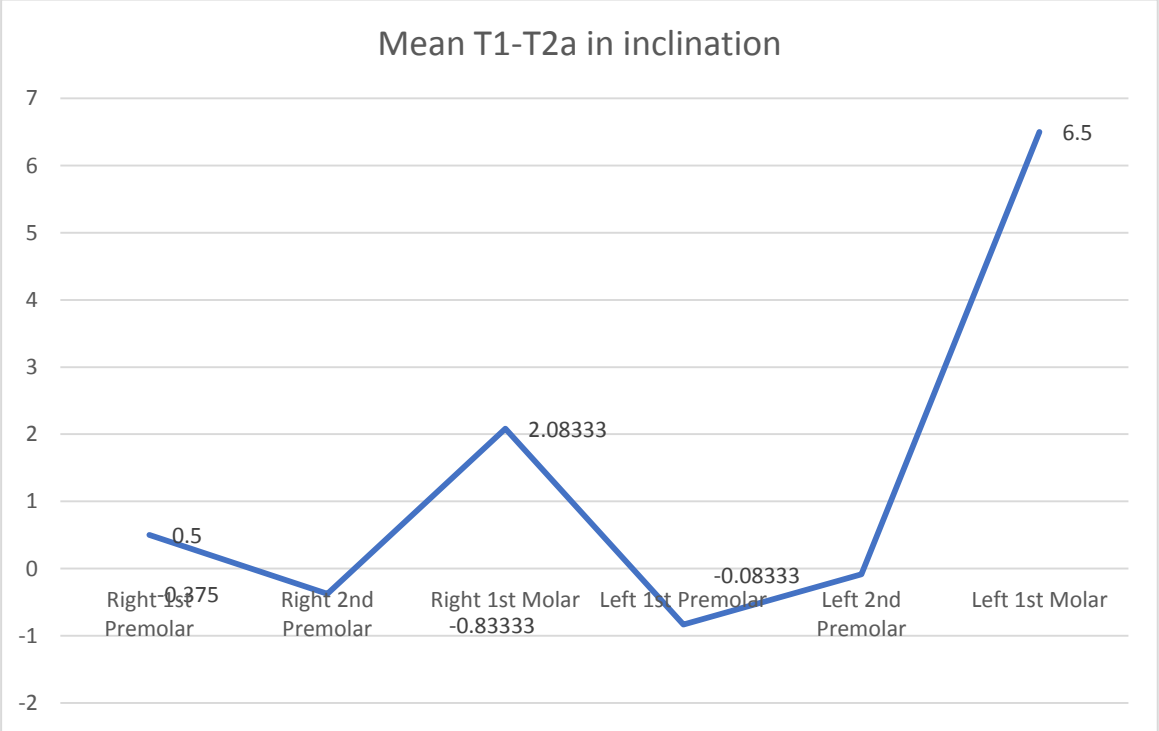


Table 9 , Graph 8 indicated that only tooth 14 showed a statistically significant difference (p = 0.015), with a mean positional change of 0.5 mm. The changes in all other teeth (15, 16, 24, 25, and 26) were not statistically significant (p > 0.05), suggesting minimal or highly variable movement in those areas.

Table 10. Paired Comparison of Inclination at T2p and T2a

	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		p-value
				Lower Bound	Upper Bound	
14	-.75000	.75378	.21760	-1.22893	-.27107	0.005
15	-.75000	.81184	.23436	-1.26582	-.23418	0.008
16	.70833	4.31413	1.24538	-2.03274	3.44940	0.581
24	-1.04167	2.50870	.72420	-2.63562	.55228	0.178
25	-1.58333	1.88092	.54298	-2.77842	-.38825	0.014
26	4.62500	20.46185	5.90683	-8.37584	17.62584	0.450

Graph 9. Paired Comparison of Inclination at T2p and T2a

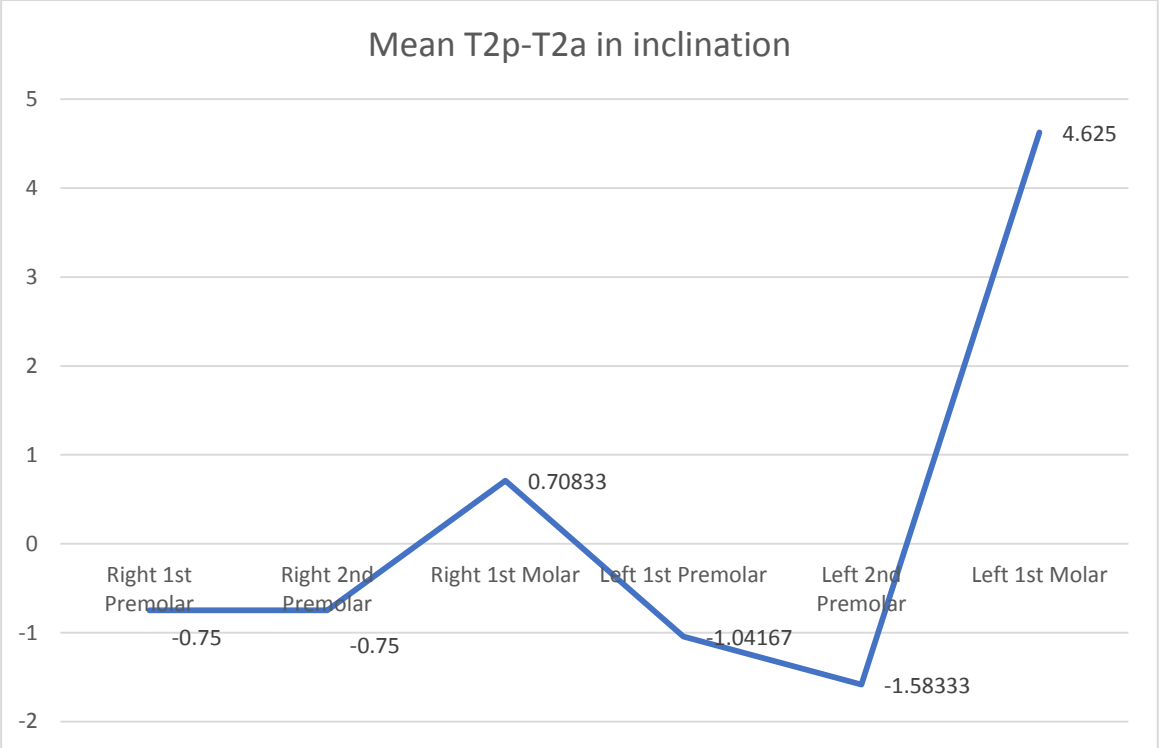


Table 10 , graph 9 shows Statistically significant positional changes were found for teeth 14, 15, and 25 ($p < 0.05$). These changes reflect measurable treatment effects at those sites. However, teeth 16, 24, and 26 did not show significant changes ($p > 0.05$), likely due to high variability or minimal movement.

Table 11. Comparison of linear Transverse measurement T1 among Males Vs Females

		N	Mean	Std. Deviation	Std. Error Mean	p-value
Canine ICW	Male	5	34.2000	3.34664	1.49666	0.144
	Female	7	31.3571	2.17398	.82169	
1st Premolar IPM1W	Male	5	41.8000	3.56371	1.59374	0.290
	Female	7	39.4286	3.64496	1.37766	
2nd Premolar IPM2W	Male	5	46.0000	2.34521	1.04881	0.071
	Female	7	42.8571	3.02372	1.14286	
1st Molar Mesial Cusp IM1MC	Male	5	49.3000	2.28035	1.01980	0.235
	Female	7	47.7143	1.79947	.68014	
1st Molar Distal Cusp IM1DC	Male	5	51.6000	3.04959	1.36382	0.329
	Female	7	49.9286	2.16850	.81961	
1st Molar trans palatal TP M1	Male	5	33.4000	2.70185	1.20830	0.616
	Female	7	34.1429	1.95180	.73771	
2nd Molar Mesial Cusp IM2MC	Male	5	52.8000	9.20326	4.11582	0.933
	Female	7	52.4286	2.22539	.84112	
2nd Molar Distal Cusp IM2DC	Male	5	57.8000	2.58844	1.15758	0.083
	Female	7	51.2143	8.17444	3.08965	
2nd Molar trans palatal TP M2	Male	5	39.4000	3.04959	1.36382	0.353
	Female	7	37.8571	1.86445	.70470	

Graph 10. Comparison of linear Transverse measurement T1 among Males Vs Females

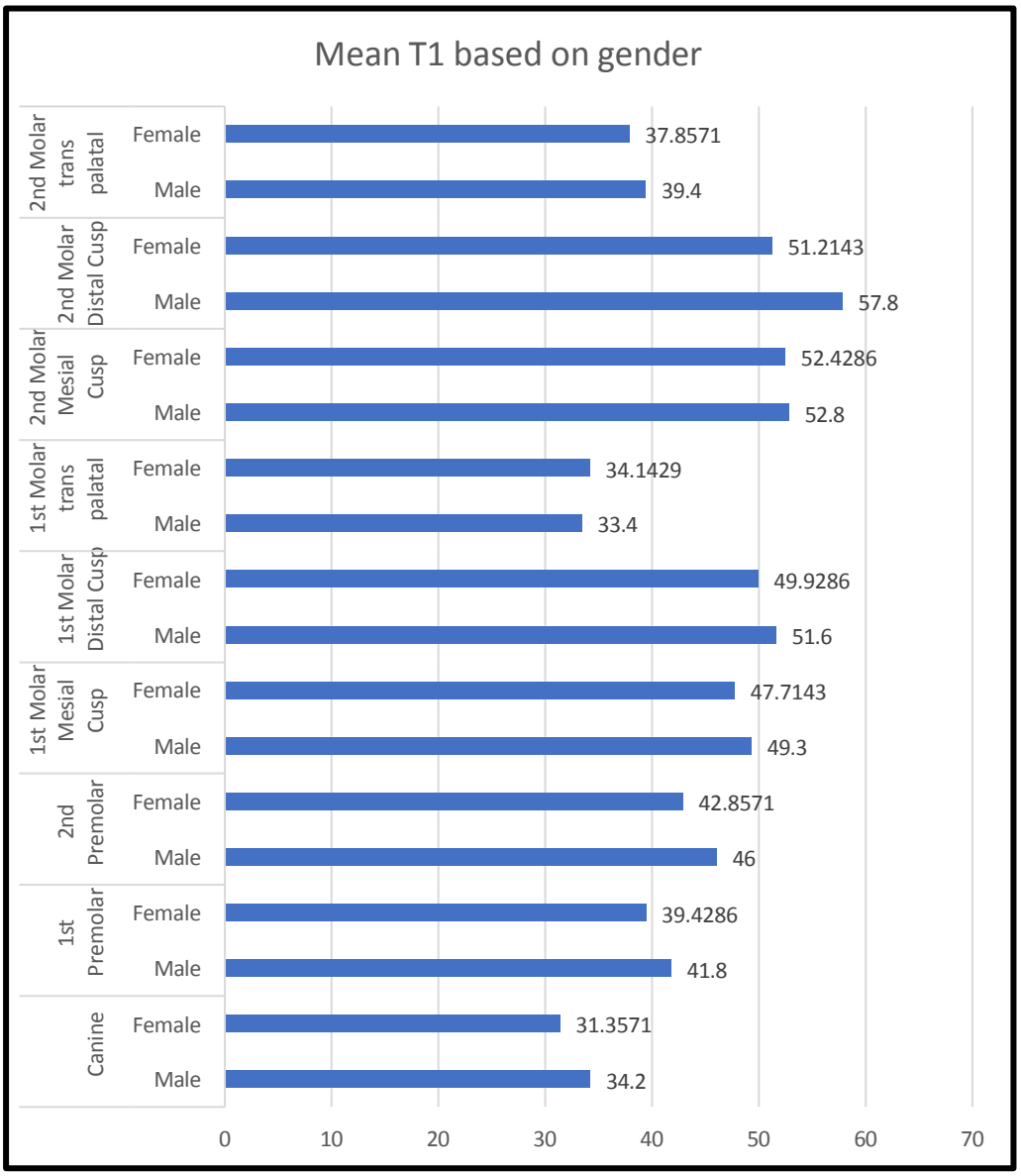


Table 12. Comparison of linear Transverse measurement at T2p among Males Vs Females

		N	Mean	Std. Deviation	Std. Error Mean	p-value
Canine ICw	Male	5	36.4000	3.43511	1.53623	0.161
	Female	7	33.5714	2.49046	.94130	
1st Premolar IPM1W	Male	5	44.2000	3.96232	1.77200	0.289
	Female	7	41.9286	2.09023	.79003	
2nd Premolar IPM2W	Male	5	48.0000	2.34521	1.04881	0.109
	Female	7	45.1429	3.27509	1.23787	
1st Molar Mesial Cusp IM1MC	Male	5	51.4000	1.94936	.87178	0.169
	Female	7	49.7143	1.86764	.70590	
1st Molar Distal Cusp IM1DC	Male	5	54.2000	2.86356	1.28062	0.126
	Female	7	51.5714	2.12972	.80496	
1st Molar trans palatal TP M1	Male	5	35.6000	2.50998	1.12250	0.609
	Female	7	36.3571	2.32225	.87773	
2nd Molar Mesial Cusp IM2MC	Male	5	58.8000	2.16795	.96954	0.006*
	Female	7	54.2143	2.15749	.81545	
2nd Molar Distal Cusp IM2DC	Male	5	60.0000	1.96850	.88034	0.005*
	Female	7	55.7857	1.67971	.63487	
2nd Molar trans palatal TP M2	Male	5	41.0000	3.31662	1.48324	0.522
	Female	7	39.8571	2.13530	.80707	

Graph 11. Comparison of linear Transverse measurement at T2p among Males Vs Females

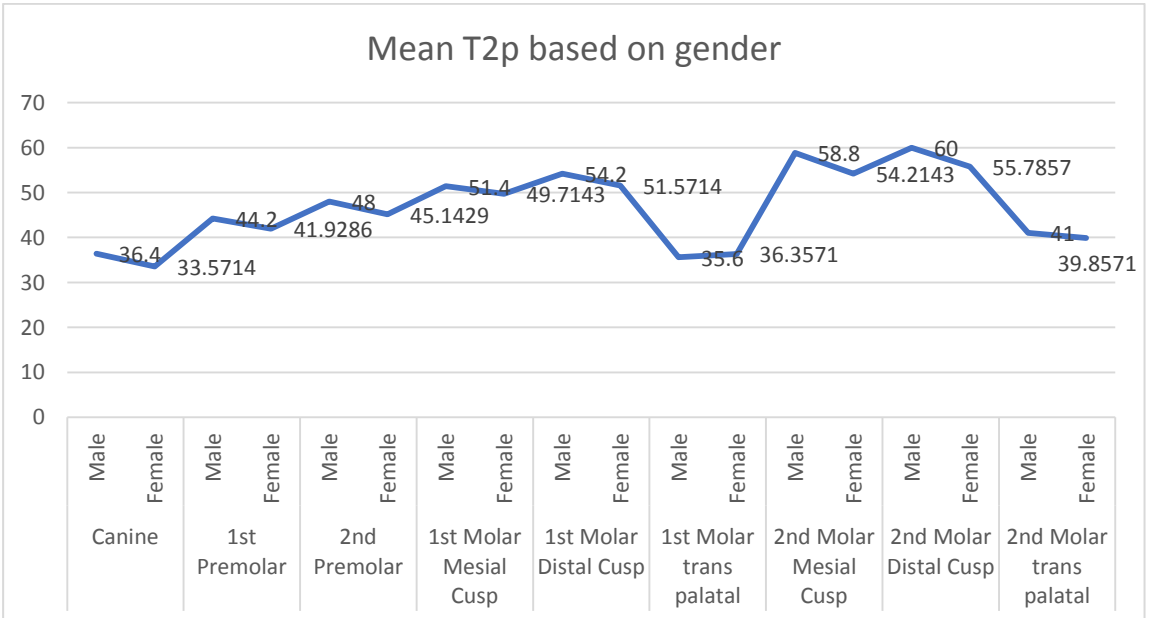


Table 12, graph 11 Statistically significant differences between males and females were observed at the 2nd molar mesial cusp ($p = 0.006$) and distal cusp ($p = 0.005$), with males showing greater transverse widths.

Table 13. Comparison of linear Transverse measurement at T2a among Males Vs Females

		N	Mean	Std. Deviation	Std. Error Mean	p-value
Canine ICW	Male	5	35.4000	3.43511	1.53623	0.172
	Female	7	32.6429	2.56116	.96803	
1st Premolar IPM1W	Male	5	43.1000	4.00625	1.79165	0.216
	Female	7	39.9286	4.16762	1.57521	
2nd Premolar IPM2W	Male	5	47.1000	2.21923	.99247	0.103
	Female	7	44.3571	3.07834	1.16350	
1st Molar Mesial Cusp IM1MC	Male	5	50.5000	2.12132	.94868	0.114
	Female	7	48.4286	1.78952	.67637	
1st Molar Distal Cusp IM1DC	Male	5	53.0000	2.76134	1.23491	0.128
	Female	7	50.5000	2.00000	.75593	
1st Molar trans palatal TP M1	Male	5	34.3000	2.16795	.96954	0.520
	Female	7	35.1429	2.11570	.79966	
2nd Molar Mesial Cusp IM2MC	Male	5	57.9000	2.77038	1.23895	0.022*
	Female	7	53.5714	2.28087	.86209	
2nd Molar Distal Cusp IM2DC	Male	5	58.6000	2.81514	1.25897	0.043*
	Female	7	55.0000	1.70783	.64550	
2nd Molar trans palatal TP M2	Male	5	39.9000	3.09031	1.38203	0.649
	Female	7	39.1429	2.07594	.78463	

Graph 12. Comparison of linear Transverse measurement at T2a among Males Vs Females

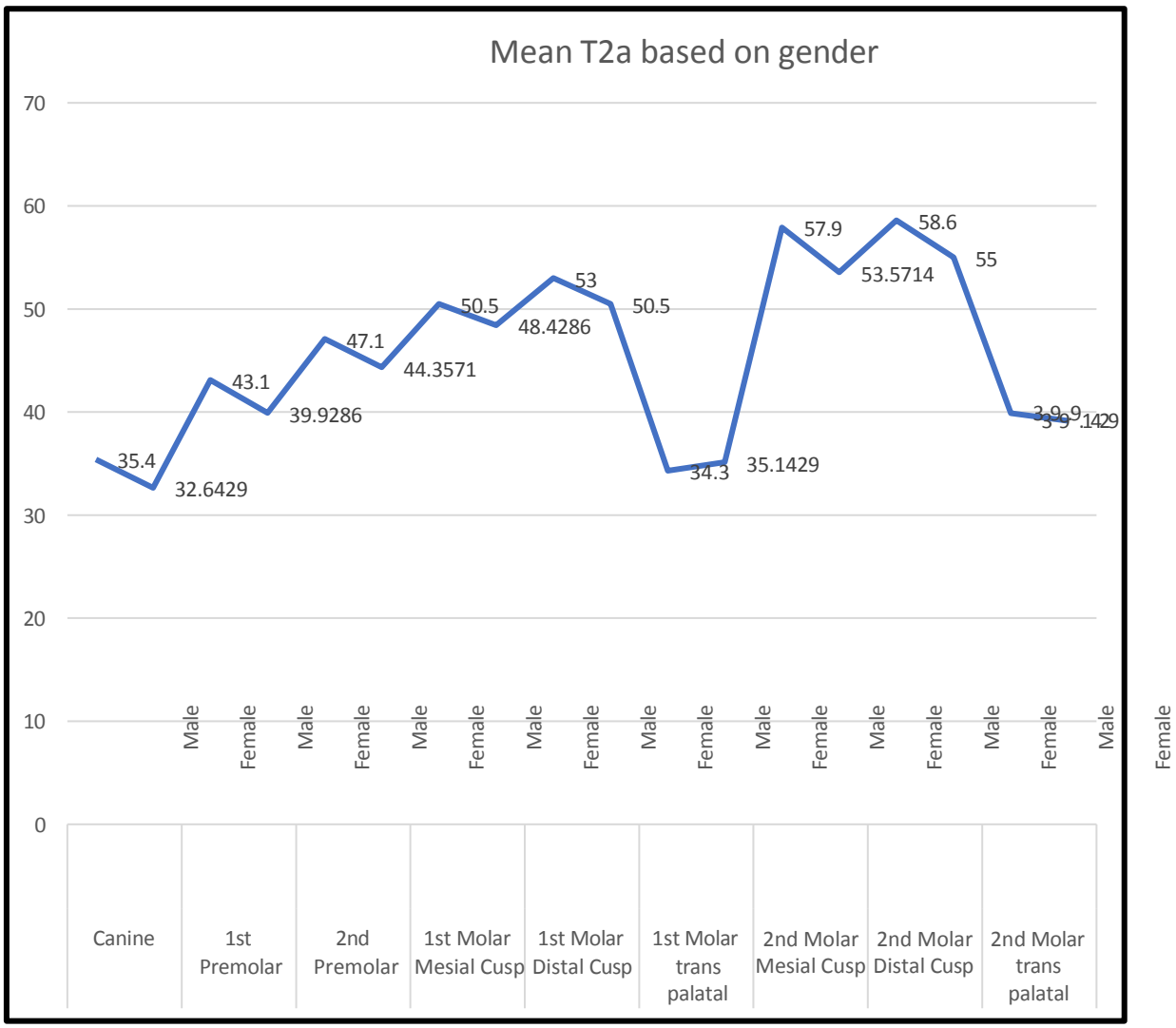


Table – 13 Graph 12, shows that there is no widespread gender-based difference in the effectiveness of clear aligner therapy for maxillary expansion, except in the second molar region

Table 14. Comparison of Inclination T 1 among Right Vs Left

	GRP	N	Mean	Std. Deviation	Std. Error Mean	p-value
First Premolar	Right	12	83.1667	3.32575	.96006	0.094
	Left	12	80.5417	3.97411	1.14723	
Second Premolar	Right	12	80.2917	2.02774	.58536	0.066
	Left	12	78.0833	3.34279	.96498	
First Molar	Right	12	76.4167	4.38403	1.26556	0.929
	Left	12	76.2500	4.65393	1.34347	

Graph 13. Comparison of Inclination T 1 among Right Vs Left

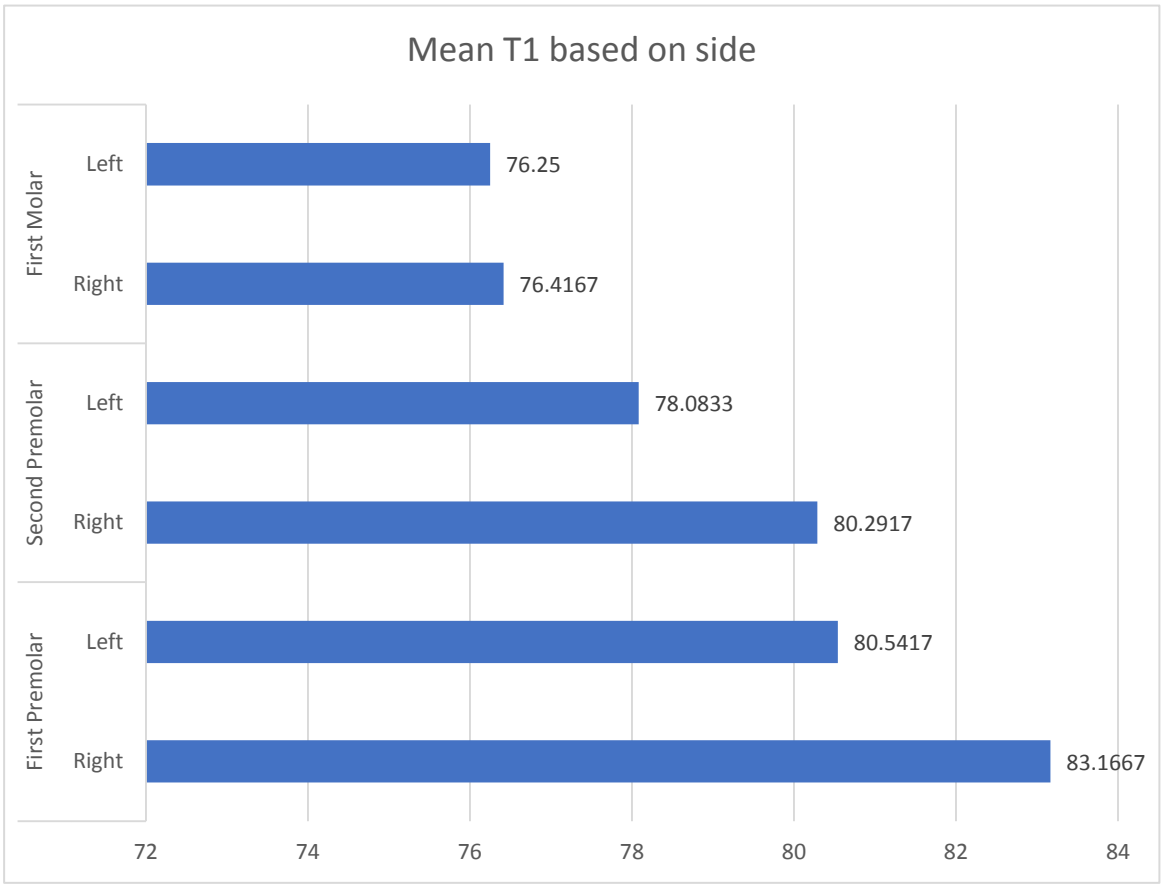


Table 15. Comparison of Inclination T 2p among Right Vs Left

	GRP	N	Mean	Std. Deviation	Std. Error Mean	p-value
First Premolar	Right	12	84.4167	3.41010	.98441	0.032*
	Left	12	80.7500	4.33013	1.25000	
Second Premolar	Right	12	80.5833	2.85110	.82304	0.195
	Left	12	78.8333	3.52480	1.01752	
First Molar	Right	12	77.7917	4.26113	1.23008	0.857
	Left	12	78.1250	4.69102	1.35418	

Graph 14 . Comparison of Inclination T 2p among Right Vs Left

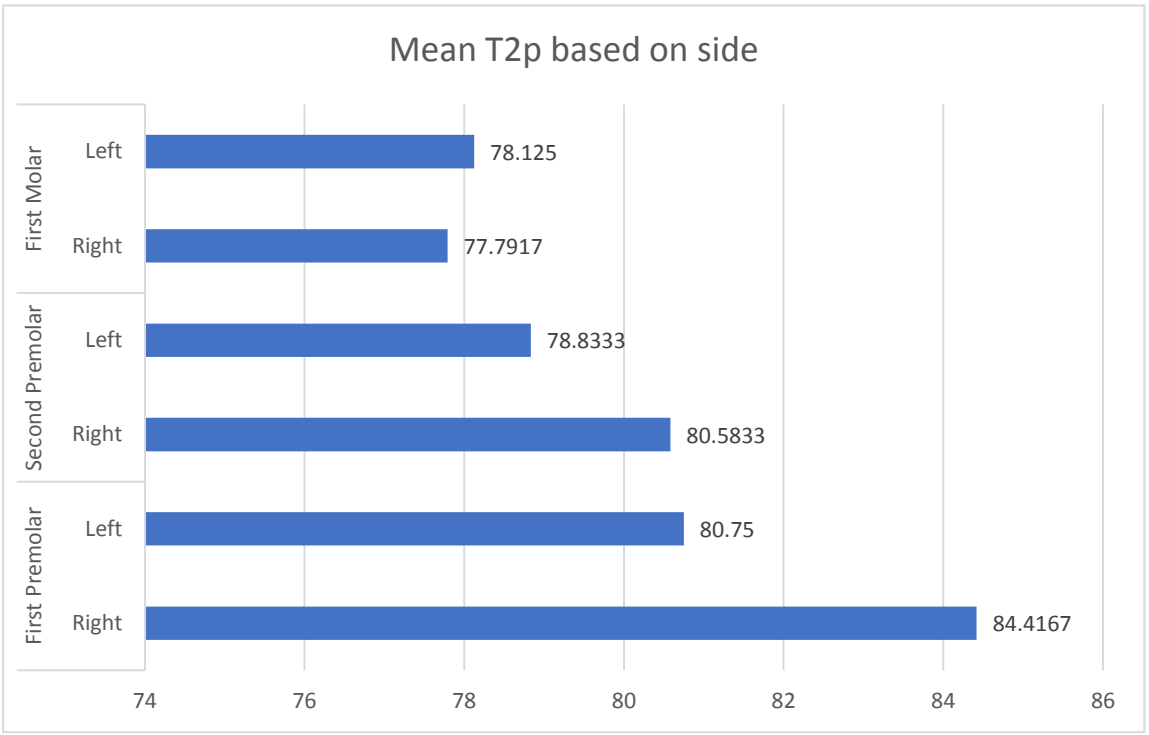
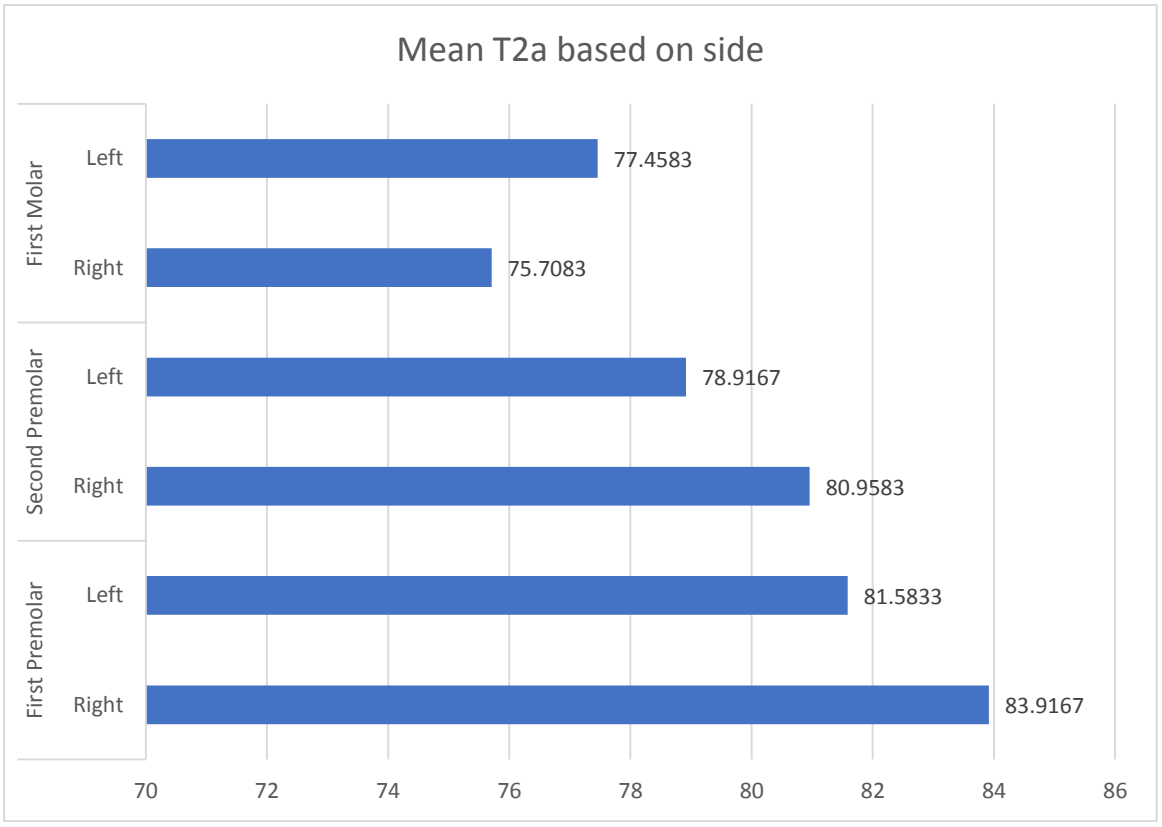


Table 15, Graph 14 shows , no significant differences were found between the right and left sides for the second premolar (p = 0.195) or the first molar (p = 0.857), suggesting symmetry in these areas. These results highlight that, within this sample, only the first premolar exhibited a statistically significant side-related variation.

Table 16. Comparison of Inclination T2 among Right Vs Left

	GRP	N	Mean	Std. Deviation	Std. Error Mean	p-value
First Premolar	Right	12	83.9167	3.14667	.90836	0.120
	Left	12	81.5833	3.86613	1.11606	
Second Premolar	Right	12	80.9583	2.36891	.68385	0.116
	Left	12	78.9167	3.57919	1.03322	
First Molar	Right	12	75.7083	3.06341	.88433	0.326
	Left	12	77.4583	5.16746	1.49172	

Graph 15. Comparison of Inclination T2 among Right Vs Left



According to table16, graph 14, no statistically significant differences were observed between the right and left sides for any of the measured teeth.

Discussion

DISCUSSION

In recent years, the advent of clear aligner therapy (CAT) has transformed the landscape of orthodontic treatment, offering patients a more esthetically pleasing and comfortable alternative to fixed appliances. Initially designed for minor tooth alignment, advances in digital treatment planning, material science, and biomechanics have expanded the indications for CAT to include more complex movements, such as maxillary expansion.[19,25] Despite the growing use of aligners for arch expansion, concerns remain regarding the predictability of treatment outcomes, especially when compared to traditional expansion modalities. Studies suggest that while aligners can induce significant increases in arch width, the mechanism is primarily dentoalveolar—dominated by buccal tipping rather than bodily translation—raising questions about their long-term stability and skeletal effectiveness.[30,33] Given the increasing demand for minimally invasive, esthetically acceptable orthodontic solutions, there is a critical need to assess the true effectiveness of CAT in achieving transverse expansion and to quantify the gap between planned and actual outcomes.

The current study aimed to evaluate the effectiveness and predictability of clear aligner therapy (CAT) in achieving maxillary expansion by comparing the digitally planned transverse expansion with the actual clinical outcomes. Knowing the accuracy of the software at predicting changes could help the practitioner to anticipate the need of overcorrection, thereby reducing refinements, midcourse corrections, and treatment time The parameters assessed included intercanine, interpremolar, and intermolar widths, as well as buccolingual inclination of the posterior teeth, at three different time points: before treatment (T1), post-treatment as planned digitally (T2p), and post- treatment as achieved clinically (T2a).

The Shapiro–Wilk test (Table 1) showed non-significant results ($p > 0.05$) for all variables, confirming that the data were normally distributed and suitable for parametric analysis. The results from Table 2 demonstrate excellent reliability across all dental landmarks evaluated (ICC > 0.9), with many measurements showing values approaching or equal to 1.000. According to commonly accepted interpretation thresholds, an ICC value above 0.9 is considered excellent, between 0.75 and 0.9 is good, 0.5 to 0.75 is moderate, and below 0.5 is poor.

The analysis revealed statistically significant differences across all teeth between T1 and T2p ($p < 0.001$), confirming that substantial expansion was planned as part of the treatment design. This was evident in regions such as the canine and premolars, where planned expansions were in the range of 2–2.5 mm. This alignes with the finding of Ali et al , they stated that dentoalveolar expansion is possible with Invisalign and can be an alternative to interproximal reduction.[26] In their 2001 study on the use of Invisalign to treat complex malocclusion, Boyd and wlaskalic noted that buccal expansion can be accomplished to change the arch's shape or reduce crowding.[25] There would be a 2–4 mm range of expansion. In their 2013 study**,** Malik et al indicated that the use of Invisalign is warranted for addressing crowding issues ranging from 1 to 5 mm.[67]

While the descriptive data in Table 3 indicated a consistent trend of increase in arch width from the pre-treatment (T1) to the actual post-treatment stage (T2a), the expansion achieved was consistently less than what was digitally planned (T2p). None of the measured differences reached statistical significance ($p > 0.05$), though the first molar mesial cusp region approached significance ($p = 0.057$), suggesting that the discrepancy between planned and achieved expansion may be clinically relevant.

These findings are consistent with previous literature reporting a degree of underexpression in transverse movements with clear aligners. Li N Wang et al[53] found that buccal expansion in the molar region was only partially achieved, with the effectiveness decreasing in more posterior segments. This trend was also echoed by Houle et al[28] who noted that while aligners are effective in achieving controlled anterior expansion, the predictability diminishes in the posterior segments due to increased resistance from surrounding structures.

In the current study, the greatest discrepancy was observed in the second molar region, where a planned expansion of 2.20 mm resulted in only 1.27 mm of actual movement. This reinforces the idea that posterior teeth are less responsive to aligner-driven transverse forces. Possible reasons include limitations in aligner material elasticity, tipping rather than bodily movement, and lack of sufficient anchorage in the posterior segments. To address these limitations, several authors, including Zhou and Guo[30] and Loberto et al[52], advocate for incorporating overcorrection into digital setups to compensate for the commonly observed underexpression of expansion movements

Table 4 from the result demonstrated statistically significant increases in transverse maxillary widths between the pre-treatment (T1) and the planned stage (T2p) usingclear aligners. The paired t-test results confirmed expansion at every measured site, with p-values < 0.001, indicating high statistical significance. These findings align with and contribute to the growing evidence base supporting the efficacy of clear aligner therapy (CAT) in achieving planned transverse arch development.

Our results are consistent with those of Zhao et al[27] who reported increases in upper arch width across multiple regions with expansion efficiencies ranging from 29% to 70%,

noting greater expansion at premolars and anterior sites, and reduced outcomes in posterior molars due to greater buccal tipping. Similarly, Houle et al[28] observed a mean expansion accuracy of 72.8% in the maxilla, although they noted ClinCheck tends to overestimate bodily movement, often resulting in more tipping than predicted.

In our cohort, the largest mean differences were recorded at the canine (2.58 mm), 1st premolar (2.17 mm), and 2nd premolar (2.13 mm) regions, which is consistent with findings by Lione et al[37] and Vidal-Bernárdez et al[28] who documented maximum expansion at premolars, suggesting that this region may be more responsive to aligner-induced forces. Our measured expansion values were generally greater than those observed in Zhou and Guo[30], who reported limited bodily expansion and overall efficiency of 36.35% at the molar level. This could be attributed to differences in sample demographics, planned expansion amounts, or the use of optimized attachments and overcorrection protocols in our digital setups.

The predictability of expansion has been a recurrent concern in aligner studies. Morales-Burruezo et al[33] and Rocha et al[50] both emphasized a consistent underexpression of programmed expansion, especially in the posterior segments. In contrast, our planned expansion showed robust statistical significance across all regions, suggesting a more predictable outcome when aligners are used with precise planning and torque control. However, like in Galluccio et al[43], we recognize that gingival-level changes tend to show more variability than cusp-level expansions, underscoring the need for overcorrection strategies in virtual setups.

Biomechanically, our findings are in agreement with Yao et al[47] and Zhang et al[46] who used finite element analysis to show that aligner-based expansion largely results in dentoalveolar effects—primarily crown tipping—rather than true bodily or skeletal expansion. The increased expansion observed in our study, especially at the canine and premolar levels, may reflect the influence of aligner thickness, optimized attachments, and arch form manipulation, as described by Li et al[53] and Suzuki et al[55].

Importantly, despite the magnitude of planned expansion, studies such as Figueiredo et al[48] and Nguyen[61] have reported that such interventions do not compromise alveolar bone integrity when carefully executed. These findings, along with our results, highlight the safety and effectiveness of controlled expansion with aligners in adult populations, especially when guided by 3D digital planning and periodontal considerations.

The paired comparison between pre-treatment (T1) and actual post-treatment (T2a) transverse dental measurements in table 5 demonstrated statistically significant increases across all evaluated sites, from the canine to the second molar region ($p < 0.01$). While this confirms that clear aligners are effective in producing maxillary arch expansion, the achieved changes were consistently smaller than the planned expansions, reinforcing the notion of underexpression of programmed transverse movements.

Our findings align with those of Morales-Burruezo et al,[33] who reported significant discrepancies between planned and achieved widths, with mean underexpressions ranging from 0.63 mm at the canines to 0.69 mm at the first molars, and minimal change at the second molars (0.25 mm). This pattern closely mirrors our results, where the actual expansion at second molars (0.83–1.21 mm) was significantly lower than planned, despite achieving statistically significant gains.

Similarly, Zhou and Guo[30] documented an average efficiency of only 36.35% for bodily expansion at the first molar level, with a predominance of crown tipping rather than true root movement. These findings were echoed in our cohort, where although linear expansion was observed, the values suggest that the movement was largely dentoalveolar in nature, likely driven by buccal crown tipping.

The biomechanical explanations for these outcomes have been well-documented. According to Yao et al[47] and Zhang et al[46], finite element analysis reveals that aligner-induced expansion exerts force primarily at the crown level, with limited torque control unless supplemented by specific attachments or modified aligner designs. Our results support this: while the directionality of expansion was consistent with the treatment goals, the magnitude remained suboptimal in most regions.

Moreover, Houle et al[28] served that ClinCheck software tends to overestimate bodily expansion and underpredict tipping tendencies—an issue that complicates digital planning accuracy. In our study, despite the statistically significant improvements from T1 to T2a, none of the achieved values matched the planned expansion magnitudes, affirming that aligners are less predictable in expressing expansion fully, particularly in posterior regions.

Notably, Galluccio et al[43] found an overall expansion accuracy of 70.88% using Invisalign®, with similar levels of underachievement across tooth types. However, the discrepancies were more pronounced at gingival measurement levels, suggesting further limitation in bodily expansion.

The implications of these findings are clinically significant. As recommended by Rocha et al[50] and Nguyen[61], incorporating overcorrection strategies in digital planning becomes essential to bridge the gap between planned and realized movements. Our data

substantiate this recommendation, particularly as none of the evaluated regions achieved their full planned expansions.

The comparison between the planned expansion (T2p) and the actually achieved expansion (T2a) in Table 6 revealed statistically significant discrepancies at all measured sites ($p < 0.05$), confirming that the intended transverse dental movements programmed in the digital setup were not fully expressed clinically. The observed accuracy of change ranged from 45.09% to 63.04%, with the lowest accuracy at the first molar mesial cusp and the highest at the canines. This pattern underscores a clinically meaningful underexpression of planned expansion, particularly in the posterior regions.

These results align closely with the findings of Zhao et al[31], who reported expansion efficiencies of 68–70% at canines and premolars, and significantly lower values (55% and 29%) at the first and second molars respectively, highlighting the challenges of posterior bodily expansion using aligners. Similarly, Morales-Burruezo et al[33] noted significant underexpression at every arch width level, with the greatest discrepancy observed at the molars.

The accuracy percentages in our study—especially the 45.09% at the first molar mesial cusp—reflect a need for biomechanical refinement. Houle et al[28] emphasized that ClinCheck software overestimates bodily movement and underrepresents crown tipping, leading to reduced accuracy in clinical outcomes. Our results corroborate this, as even with digital precision in planning, the real-world execution remains susceptible to tipping mechanics, particularly in the molar region.

Several finite element studies have provided mechanistic explanations for this phenomenon. Yao et al[27] and Zhang et al[20] demonstrated that, without auxiliary torque

control strategies, aligner-based expansion tends to result in buccal crown tipping rather than true bodily translation. The discrepancies in our T2p–T2a differences suggest that tipping may have contributed to the partial expression of planned movements, especially in posterior teeth with deeper bone anchorage and larger root surface areas.

Despite the predictability challenges, it is important to note that expansion was achieved at all levels. This supports previous reports, such as Galluccio et al[43] and Bouchant et al[44], which concluded that clear aligners are effective in producing maxillary expansion, albeit primarily through dentoalveolar changes rather than skeletal widening. This is further substantiated by Kalekar et al[60] whose meta- analysis highlighted that most expansion with aligners occurs through buccal tipping, with limited root movement and a tendency for underexpression at the molars.

Clinically, this gap between planned and actual expansion necessitates a strategic overcorrection during digital setup. As emphasized by Rocha et al[50], incorporating overcorrection protocols is critical for enhancing the predictability of expansion, especially in the posterior region where resistance to movement is greater. Our findings reinforce this clinical recommendation, particularly for molars, where aligner efficiency dropped below 50%.

Importantly, while underexpression is evident, periodontal safety remains intact. Studies by Figueiredo et al[48] and Nguyen[61] confirmed that controlled dentoalveolar expansion using clear aligners does not compromise buccal bone integrity, even in adults. This provides reassurance that despite reduced expression of planned expansion, the approach remains a biologically sound and minimally invasive treatment modality.

In line with our results, systematic review by Ma and Wang[27] note that aligner- driven expansion is “not entirely predictable”, generally reaching peak effectiveness in the mid-

arch (premolar) region and decreasing toward the posterior. Pinho et al[11] also reported that the greatest amount of expansion occurred at the premolars.

However, our data differ somewhat in that the canine showed highest efficacy, followed by second molar mesial cusp. Such discrepancies likely reflect differences in measurement methods (we used cusp distances) and treatment protocols. Overall, these studies agree that aligners produce significantly less transverse change than the computer plan. In fact, compared to fixed appliances or rapid palatal expanders (RPEs), aligners generate far lower expansion forces. In vitro work has demonstrated that RPEs can exert an order of magnitude more force than Invisalign® (30–50 N vs 3–5 N), explaining why rigid expanders achieve much greater skeletal change.

Not surprisingly, a meta-analysis found that clear aligners are generally less effective than braces at increasing arch width and controlling buccolingual torque Thus, our finding of ~40–55% efficacy per tooth is consistent with the literature indicating that aligner expansion is moderate and often requires overcorrection.

The higher efficacy observed at the second molar level (mesial cusps) likely reflects the biomechanics of aligner-induced expansion. Clear aligners tend to tip teeth buccally rather than translate them bodily, because torque control is limited. Indeed, Santucci et al. showed significantly more expansion at molar cusp tips than at gingival levels, indicating predominantly tipping motion. This tipping can rotate molars outwards, artificially increasing intermolar cusp width. In contrast, canines (with long roots and limited aligner grip) resist buccal tipping, yielding lower effective movement. An FEM study by Yao Song et al[47] note that without adequate root torque, aligner forces produce greater cuspal movement than true arch widening. We also note that newer aligner materials

(SmartTrack®) and optimized attachments can improve expansion efficiency but even so the posterior teeth often exhibit the largest increases in crown width.

In our sample, second molars (especially mesial cusps) showed the highest percent of planned expansion, consistent with study by Lione et al[37] in which they evaluated maxillary expansion with the Invisalign First System® in 23 growing subjects with a mean age of 9.4 ± 1.2 years old, with a maxillary posterior transverse interarch discrepancy. The findings of their research indicated a notable increase in the maximum width of the first primary molars when compared to the second primary molars and primary canines. Additionally, the maxillary first molars exhibited the most significant increase in mesial intermolar width, attributed to the rotation that took place during expansion around the palatal root of the hinge tooth. These findings align with our own, as the most substantial expansion was observed in the posterior regions and at the occlusal level. The overall mean efficacy of expansion in the present study ranged between 60% and 75% across different dental regions, similar to the 70–75% predictability reported by Galluccio et al[43] This suggests a need for overcorrection during virtual treatment planning to compensate for underachievement, as suggested by Lü et al.[53]

This study evaluated the inclination changes of selected posterior teeth during transverse expansion with clear aligners, using paired comparisons across three timepoints: pre-treatment (T1), planned expansion (T2p), and achieved expansion (T2a). The results indicate that while some planned inclinations were successfully expressed, others exhibited statistically significant discrepancies, highlighting variability in how well planned torque and angulation corrections are achieved during aligner therapy.

From T1 to T2p, statistically significant changes were seen in teeth 14, 16, 25, and 26 ($p < 0.05$), indicating that the digital treatment plan incorporated specific buccolingual

inclination corrections for these teeth. Teeth 15 and 24, however, did not demonstrate significant planned inclination change, suggesting those teeth either required minimal correction or that the aligner system underestimated the torque required at those positions.

When comparing T1 to T2a, only tooth 14 showed a statistically significant change in inclination ($p = 0.015$), with the rest failing to reach significance. This suggests that, although inclination correction was programmed into the aligners, it was largely underexpressed clinically—likely due to insufficient torque delivery or biological resistance. These findings align with those of Zhao et al[31] and Houle et al[48] who both emphasized that ClinCheck software tends to overestimate bodily movement and torque control, resulting in more tipping and less controlled root movement in vivo.

The T2p–T2a comparison (Table 10) further confirmed this trend: teeth 14, 15, and 25 exhibited statistically significant differences ($p < 0.05$), demonstrating underexpression of planned inclination changes. Teeth 16, 24, and 26 did not show significant differences, but this may be due to large variability (e.g., tooth 26 showed a standard deviation of over 20), which could be attributed to patient-specific anatomical variations or aligner design limitations in controlling root torque in posterior regions.

The difficulty in achieving predictable inclination changes in molars and premolars is well-supported by existing literature. Zhou and Guo[30] found an average torque expression efficiency of only 36.35% at the first molars, attributing this to the aligners' limited contact area with bulky posterior teeth and the challenges of transmitting rotational and torque forces at greater root surface areas. Yao et al[31] and Zhang et al[46] reinforced these findings through finite element analyses, demonstrating that torque control is significantly improved only with the use of optimized attachments, complete palatal coverage, or

increased aligner thickness, which were not universally used in earlier aligner designs.

Moreover, Suzuki et al[45] that conventional aligners without full palatal coverage are more prone to producing buccal crown tipping due to inadequate torque control, particularly in posterior teeth. These biomechanical limitations likely explain why significant discrepancies were observed between T2p and T2a in this study, especially at teeth 14, 15, and 25.

It is important to recognize that torque delivery in aligner systems is inherently less predictable than linear translational movements, as reported by Rocha et al[50] and Loberto et al[52] These studies emphasize that rotational and torque corrections are among the least accurate movements in aligner therapy, often requiring overcorrection, refinements, or auxiliary biomechanics to be effectively achieved.

In summary, while clear aligner therapy can induce changes in tooth inclination as part of a transverse expansion protocol, the actual expression of planned torque is inconsistent and often underexpressed, particularly in the posterior segments. This underperformance necessitates the use of overcorrection protocols, enhanced attachment designs, and aligner design modifications—such as increased rigidity or full palatal coverage—to improve clinical accuracy. Clinicians must anticipate these limitations during treatment planning and set realistic expectations for torque control with aligners.

Gender-based analysis(table 13) showed no significant differences in most arch width parameters between male and female participants, with the exception of the second molar region at both planned and achieved stages (T2p and T2a), where males demonstrated significantly greater expansion. This could reflect baseline anatomical differences in arch form and bone density Proffit et al [68] suggesting that treatment expectations may need to

be calibrated based on sex, particularly in posterior expansion cases. The marginally greater expansion observed in male patients, particularly in the posterior segments, may be attributed to anatomical and biomechanical differences between genders. Males generally have wider dental arches and more robust craniofacial structures, which may allow for more effective force distribution by the aligners. Additionally, denser alveolar bone and stronger masticatory muscles may contribute to improved anchorage and a more favorable response to orthodontic forces. These factors could lead to slightly enhanced expansion efficiency in males.

While the difference was not statistically significant, such anatomical variations suggest the importance of individualized treatment planning and the potential need for overcorrection, especially in female patients with narrower arches or thinner bone.

The comparison between right and left sides (Table 15) revealed minimal asymmetry overall. The only statistically significant difference was found in the first premolars at T2p ($p = 0.032$), indicating a slightly asymmetrical treatment plan or patient-specific anatomical asymmetry. However, at T2a, these differences were not significant, suggesting the aligners may have self-corrected minor planning asymmetries during treatment. These findings are consistent with the clinical observation that minor transverse asymmetries are often resolved with aligner wear over time .[69]

While this study provides valuable insights into the effectiveness of aligners in achieving maxillary expansion, certain aspects offer opportunities for further exploration. The use of 3D digitally printed models and Vernier calipers allowed for practical and accessible measurement of expansion; however, future studies could benefit from incorporating digital superimposition techniques or intraoral scanning to enhance measurement

precision and minimize manual variability. The sample size of twelve subjects offered an initial understanding of treatment outcomes, and expanding this in future investigations could help establish more generalized conclusions. Given the study duration of three months, the focus remained on the immediate outcomes of expansion. Longer-term studies would be instrumental in evaluating the stability of results and monitoring any potential relapse over time. As this study concentrated on model-based assessments, future research could integrate radiographic tools such as CBCT to provide a more comprehensive evaluation, distinguishing between skeletal and dental contributions to the expansion.

Conclusion

CONCLUSION

The study concludes that:

1. Clear aligner therapy achieved statistically significant transverse expansion at all evaluated sites.
2. Actual expansion achieved was significantly less than the planned expansion.
3. The accuracy of expansion achieved is 45% to 63% with lowest accuracy of 45 % achieved in the molar region and highest at canine region being 63%.
4. Statistically significant inclination changes were found in premolar region.
5. No statistically significant differences were observed in most transverse measurements between male and female patients, with the exception of the mesial and distal cusps of the second molars, where males demonstrated significantly greater expansion.
6. No statistically significant differences were observed between the right and left sides for any of the measured teeth.

Summary

SUMMARY

The aim of this study was to evaluate the effectiveness of clear aligner therapy (CAT) in achieving maxillary expansion by comparing the digitally planned expansion with the actual clinical outcomes. Additionally, the study aimed to assess changes in the inclination of premolars and molars during expansion. Clear aligner therapy has gained popularity as a patient-friendly alternative to conventional expansion techniques, and this study focused on evaluating its predictability and effectiveness in achieving transverse maxillary expansion.

A total of 12 patients undergoing clear aligner therapy for maxillary expansion were included. For each patient, three sets of digital models were analyzed: pretreatment models (T1), post-treatment digital plans (T2p) generated by treatment planning software, and post-expansion clinical models (T2a) obtained by rescanning after 16 weeks of aligner wear. Transverse measurements—intercanine, interpremolar, and intermolar widths—were recorded across these time points. In addition, molar and premolar inclinations were assessed using a stainless steel protractor, and transverse measurements were taken with a vernier caliper.

Statistical analysis was performed using the paired t-test to evaluate differences between T1, T2p, and T2a, while the independent T test was used for evaluating inclination changes and gender-based differences. The results revealed statistically significant expansion across all measured regions. However, the amount of expansion achieved clinically (T2a) was significantly less than what was digitally planned (T2p). The highest accuracy was found in the canine region, with lower predictability observed in the premolar and molar regions. The accuracy of clinical expansion compared to planned

expansion ranged between 45% and 63%, with the lowest accuracy recorded in the molar region.

Gender-based analysis showed no statistically significant differences in most transverse measurements, except for the second molar mesial and distal cusp regions, where males exhibited significantly greater expansion ($p = 0.022$ and $p = 0.043$). No significant differences were found between the right and left sides of the dental arch.

The findings confirm that while clear aligner therapy can produce significant transverse expansion, it tends to underexpress the movements planned digitally. This supports the research hypothesis and highlights the need for clinicians to account for such discrepancies in their treatment planning. Incorporating strategic overcorrections and biomechanical enhancements may help improve the predictability and overall success of maxillary expansion using clear aligners.

Bibliography

BIBLIOGRAPHY

1. L'tanya JB, White RP Jr, Proffit WR, Turvey TA. Segmental LeFort I osteotomy for management of transverse maxillary deficiency. J Oral Maxillofac Surg. 1997;55(7):728–31.
2. Patil GV, Lakhe P, Niranjane P. Maxillary expansion and its effects on circummaxillary structures: A review. Cureus. 2023;15(1):e33755.
3. Laptook T. Conductive hearing loss and rapid maxillary expansion: report of a case. Am J Orthod. 1981;80(3):325–31.
4. Agarwal A, Mathur R. Maxillary expansion. Int J Clin Pediatr Dent. 2010;3(3):139.
5. Kulshrestha R, Parkar A, Vibhute PK, Patil C, Umale V, Chandurkar K. Methods of gaining space: A review. ES J Dent Sci. 2020;1:1012.
6. Chakka CVNSS, Gohil AM, Jhankar R, Rajan M, Tomar SK, Varne SS. Expansion in orthodontics: A review. IJMACR. 2022;5(1):187–92.
7. Venkateshwaran K, Kaur S, Shaon. Slow maxillary expansion: A review. Int J Health Sci. 2021;5(S2):303–14.
8. Venkateshwara K, Soni S, Prashar A. Rapid maxillary expansion: A review. Int J Health Sci. 2021;5(S2):239–51.
9. Suri L, Taneja P. Surgically assisted rapid palatal expansion: a literature review. Am J Orthod Dentofacial Orthop. 2008;133(2):290–302.
10. Rasool I, Mittal S, Aggarwal I, Palkit T. Slow expansion in orthodontics – A review article. Int Dent J Stud Res. 2022;10(3).
11. Pinheiro FH, Garib DG, Janson G, Bombonatti R, de Freitas MR. Longitudinal stability of rapid and slow maxillary expansion. Dent Press J Orthod. 2014;19(6):70–7.

12. Colak C, Aras B, Cheng LL, Elekdag-Turk S, Turk T, Darendeliler MA. Effects of rapid and slow maxillary expansion on root resorption: a micro-computed tomography study. Eur J Orthod. 2021;43(6):682–9.

13. Ebrahimy G, Konermann A, El-Bialy T, Keilig L, Bourauel C. Comparative Experimental Evaluation of Orthodontic Appliances for Maxillary Arch Expansion. J Clin Med. 2024 Oct 29;13(21):6473. doi: 10.3390/jcm13216473.

14. Almeida MR, Futagami C, Conti AC, Oltramari-Navarro PV, Navarro RL. Dentoalveolar mandibular changes with self-ligating versus conventional bracket systems: a CBCT and dental cast study. Dent Press J Orthod. 2015;20(3):50–7.

15. Lin F, Yao L, Bhikoo C, Guo J. Impact of fixed orthodontic appliance or clear-aligner on daily performance, in adult patients with moderate need for treatment. Patient Prefer Adherence. 2016;10:1639–45.

16. Mohan S, Jain S, Ashutosh. Invisalign: The contact lenses for teeth. Subharti Dent Coll Hosp, Meerut. Indian Journal of Orthodontics and Dentofacial Research, October-December, 2015;1(1):16-22

17. Aljabaa AH. Clear aligner therapy Narrative review. J Int Oral Health. 2020;12(7):1.

18. Buschang PH, Shaw SG, Ross M, Crosby D, Campbell PM. Comparative time efficiency of aligner therapy and conventional edgewise braces. Angle Orthod. 2014 May;84(3):391-6. doi: 10.2319/062113-466.

19. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Efficacy of clear aligners in controlling orthodontic tooth movement: a systematic review. Angle Orthod. 2015 Sep;85(5):881-9. doi: 10.2319/061614-436.1.

20. Zheng M, et al. Efficiency, effectiveness and treatment stability of clear aligners: a systematic review and meta-analysis. Orthod Craniofac Res. 2017;20(3):127–33.

21. Ke Y, Zhu Y, Zhu M. A comparison of treatment effectiveness between clear aligner and fixed appliance therapies. BMC Oral Health. 2019;19(1):1–10.

22. Phan X, Ling PH. Clinical limitations of Invisalign. J Can Dent Assoc. 2007;73(3).

23. Galan-Lopez L, Barcia-Gonzalez J, Plasencia E. A systematic review of the accuracy and efficiency of dental movements with Invisalign®. Korean J Orthod. 2019;49:140–9.

24. Lione R, Paoloni V, Bartolommei L, Gazzani F, Meuli S., Pavoni C, & Cozza P. Maxillary arch development with Invisalign system. Angle Orthod., 2021;91(4), 433–440

25. Boyd RL, Waskalic V. Three-dimensional diagnosis andorthodontic treatment of complex malocclusions with the invisalign appliance. Semin Othod 2001;7 (4): pp. 274-293.

26. Ali O, Gonzalez M, Kimme-Smith C. The effectiveness of dentoalveolar expansion using Invisalign. J Orthod Sci. 2012;1(2):52–8.

27. Zhao X, Wang HH, Yang YM, Tang GH. Maxillary expansion efficiency with clear aligner and its possible influencing factors. Chin J Stomatol., 2017; 52(9), 543–548

28. Houle JP, Piedade L, Todescan R Jr, Pinheiro FH. The predictability of transverse changes with Invisalign. Angle Orthod. 2017 ;87(1):19-24.

29. Solano-Mendoza B, Sonnemberg B, Solano-Reina E, Iglesias-Linares A. How effective is the Invisalign® system in expansion movement with Ex30' aligners? Clin Oral Investig. 2017 ;21(5):1475-1484.

30. Zhou N, Guo J. Efficiency of upper arch expansion with the Invisalign system. Angle Orthod. 2020 Jan;90(1):23-30.

31. Fiori A, Minervini G, Nucci L, d'Apuzzo F, Perillo L, Grassia V. Predictability of crowding resolution in clear aligner treatment. Prog Orthod. 2022 ;23(1):43.

32. Sun P, Xin Y. Arch expansion efficiency of clear aligner on patients with mixed dentition using 3ship digital oral scanner. J Biomed Nanotechnol.2022;18(12):2786-93

33. Morales-Burruezo I, Gandía-Franco JL, Cobo J, Vela-Hernández A, Bellot-Arcís C. Arch expansion with the Invisalign system: Efficacy and predictability. PLoS One. 2020;15(12):e0242979.

34. Barreda GJ, Dzierewianko EA, Mazza V, Muñoz KA, Piccoli GI, Romanelli HJ. Expansion treatment using Invisalign®: Periodontal health status and maxillary buccal bone changes. A clinical and tomographic evaluation. Orthod Sci Pract. 2020;33(2):69–81.

35. Horani S, El-Bialy T, Barmak AB, Rossouw PE, Michelogiannakis D. Changes in airway dimensions following non-extraction clear aligner therapy in adult patients with mild-to-moderate crowding. J Contemp Dent Pract.. 2021;22(3):224-30

36. Levrini L, Carganico A, Abbate L. Maxillary expansion with clear aligners in the mixed dentition: A preliminary study with Invisalign® First system. Eur J Paediatr Dent. 2021;22(2):125-1287)

37. Lione R, Paoloni V, Bartolommei L, Gazzani F, Meuli S, Pavoni C, Cozza P. Maxillary arch development with Invisalign system. Angle Orthod. 2021 ;91(4):433-440.

38. Vidal-Bernárdez ML, Vilches-Arenas Á, Sonnemberg B, Solano-Reina E, Solano-Mendoza B. Efficacy and predictability of maxillary and mandibular expansion with the Invisalign® system. J Clin Exp Dent. 2021 Jul 1;13(7):e669-e677

39. Cretella Lombardo E, Paoloni V, Fanelli S, Pavoni C, Gazzani F, Cozza P. Evaluation ofthe Upper Arch Morphological Changes after Two Different

Protocols of Expansion in Early Mixed Dentition: Rapid Maxillary Expansion and Invisalign® FirstSystem. Life 2022;12:1323.

40. Perrotti G, Carrafiello A, Rossi O, Karanxha L, Baccaglione G, Del Fabbro M. Clinical Use of Aligners Associated with Nuvola® OP System for Transverse Maxillary Deficiency: A Retrospective Study on 100 Patients Int J Environ Res Public Health. 2022 ;19(9):5751.

41. Pan B, MacIntosh D, Njie R, Lui A, Westover L, El-Bialy T. The Effect of Upper Arch Expansion by Clear Aligners on Nasal Airway Volume in Children: A Preliminary Study. Applied Sciences. 2025; 15(4):2134.

42. D'Antò V, Valletta R, Di Mauro L, Riccitiello F, Kirlis R, Rongo R. The predictability of transverse changes in patients treated with clear aligners. Materials. 2023;16(5):1910.

43. Galluccio G, De Stefano AA, Horodynski M, Impellizzeri A, Guarnieri R, Barbato E, Di Carlo S, De Angelis F. Efficacy and accuracy of maxillary arch expansion with clear aligner treatment. Int J Environ Res Public Health. 2023;20(5):4634.

44. Bouchat M, Saade A, El Helou M. Is maxillary arch expansion with Invisalign® efficient and predictable? A systematic review. Int Orthod. 2023 Mar 27;21(2):100750

45. Suzuki S, Nakano H, Kataoka Y, Maki K. Clear aligner orthodontic force and conformity during lateral expansion. Clin Investig Orthod.2023;82(2):67-74.

46. Zhang Y, Hui S, Gui L, Jin F. Effects of upper arch expansion using clear aligners on different stride and torque: a three-dimensional finite element analysis. BMC Oral Health. 2023;23(1):891.

47. Yao S, Jiang W, Wang C, He Y, Wang C, Huang L. Improvements of tooth movement efficiency and torque control in expanding the arch with clear aligners:

a finite element analysis. Frontiers in Bioengineering and Biotechnology. 2023;11:1120535

48. Figueiredo MA, Romano FL, Feres MFN, Stuani MBS, Lima Ferreira JT, Nahás ACR, Matsumoto MAN. Maxillary alveolar bone evaluation following dentoalveolar expansion with clear aligners in adults: A cone- beam computed tomography study. Korean J Orthod 2023;53(4):264-275.

49. Nogal-Coloma A, Yeste-Ojeda F, Rivero-Lesmes JC, Martin C. Predictability of Maxillary Dentoalveolar Expansion Using Clear Aligners in Different Types of Crossbites. Applied Sciences. 2023;13(5):2963.

50. Rocha AS, Gonçalves M, Oliveira AC, Azevedo RM, Pinho T. Efficiency and Predictability of Coronal Maxillary Expansion Repercussion with the Aligners System: A Retrospective Study. Dentistry Journal. 2023;11(11):258.

51. Keilig L, Brieskorn L, Schwarze J, Schupp W, Bourauel C, Konermann A. Treatment Efficiency of Maxillary and Mandibular Orovestibular Tooth Expansion and Compression Movements with the Invisalign® System in Adolescents and Adults. J Clin Med. 2024;13(5):1267.

52. Loberto S, Pavoni C, Fanelli S, Lugli L, Cozza P, Lione R. Predictability of expansion movements performed by clear aligners in mixed dentition in both arches: a retrospective study on digital casts. BMC Oral Health. 2024;24(1):694.

53. Li N, Wang C, Yang M, Chen D, Tang M, Li D, Qiu S, Chen Q, Feng Y. Effects of different tooth movement patterns and aligner thicknesses on maxillary arch expansion with clear aligners: a three-dimensional finite element study. Front Bioeng Biotechnol. 2024;12:1424319.

54. Lin, Tian-Wei, Zhang, Jing-Lan, Chen, Lin, Chen, Zheng, Ai Hong, Mai, Zhi-Hui . Impact of Invisalign® first system on molar width and incisor torque in malocclusion during the mixed dentition period. Medicine. 2024;103(27):38742.

55. Qinyi LÜ, Ziqi GA, Qingchen FE, Hongxiang ME, Juan LI. Optimizing arch expansion with clear aligners in the mixed dentition based on finite element analysis. J Shanghai Jiao Tong Univ (Med Sci). 2024;44(8):935.

56. Karslı N, Ocak I, Akyıldız M, Gögen H, Dalci O. Evaluation of the effect of different attachment configurations on molar teeth in maxillary expansion with clear aligners–a finite element analysis. BMC Oral Health. 2024;24(1):921.

57. Bruni A, Ferrillo M, Gallo V, Parrini S, Garino F, Castroflorio T, Deregibus A. Efficacy of clear aligners vs rapid palatal expanders on palatal volume and surface area in mixed dentition patients: A randomized controlled trial. Am J Orthod Dentofacial Orthop.2024;166(3):203-14.

58. Silvestrini-Biavati F, Imenpour S, Poli F, Kola E, Abate A, Lanteri V, Ugolini A. Three-Dimensional Analysis of Maxillary Expansion during Mixed Dentition: Comparison between Leaf Expander and Aligners A Case-Control Study. Applied Sciences. 2024;14(19):8700.

59. Rozzi M, Mucedero M, Fanelli S, Bollero P, Cozza P. Preadolescents' Smile Outcomes after Two Different Orthodontic Treatments: Traditional Interceptive Therapy with Rapid Maxillary Expansion (RME)/Schwarz Plate and Clear Aligners. Applied Sciences. 2024 ;14(20):9325.

60. Kalekar AA, Manchanda J, Chavan S, Bhad WA, Atram H, Badu P, Tarde P. Effectiveness of maxillary arch expansion using clear aligners in adult patients: a systematic review and meta-analysis. Aust Orthod J. 2024;40:111-29.

61. Nguyen KV. Buccal alveolar bone changes in adult non-extraction clear aligner patients: a retrospective CBCT study [dissertation]. Seattle (WA): University of Washington; 2024.

62. Rojas GA, García-Melo JI, Aristizábal JS. Finite Element Simulation of Biomechanical Effects on Periodontal Ligaments During Maxillary Arch Expansion with Thermoformed Aligners. J Funct Biomater. 2025 Apr 17;16(4):143. doi: 10.3390/jfb16040143.

63. Kim, So Hee. Prescribing Targeted Expansion With Aligners. MS thesis. Saint Louis University, 2024. 31763787.

64. Bucur SM, Moga RA, Olteanu CD, Bud ES, Vlasa A. A Retrospective Study Regarding the Efficacy of Nuvola® OP Clear Aligners in Maxillary Arch Expansion in Adult Patients. Diagnostics. 2025;15(6):738.

65. Meuli S, Gentile D, Garcovich D, Giuliante L, Staderini E, Cordaro M. Correlation between transverse and sagittal dimensions in early stage: a retrospective study between patients treated with clear aligners and untreated patients. BMC Oral Health. 2025 ;25(1):1-9.

66. Cengiz SM, Goymen M. The effectiveness of orthodontic treatment with clear aligners in different thicknesses. Scientific Reports. 2025;15(1):3958.

67. Malik OH, McMullin A, Waring DT. Invisible orthodontics part 1: invisalign. Dent Update. 2013 Apr;40(3):203-4, 207-10, 213-5.

68. Proffit WR, Fields HW, Sarver DM. Contemporary Orthodontics. 6th ed. St. Louis: Elsevier; 2019.

69. Weir T. Clear aligners in orthodontics: Benefits and limitations. Aust Dent J. 2017;62(Suppl 1):58–62.

Annexures

ANNEXURE – I

CLINIC CONSENT FORM

सन्तोष डेन्टल कॉलेज

प्रताप विहार, गाजियाबाद

सहमति पत्र

1. मै .....पुत्र/पत्नी.....निवासी.....
..... अपने ऊपर किये जाने वाले निरीक्षण/ परीक्षण, चिकित्सीय सलाह/पद्धति की पूर्ण सहमति देता/देती हु।

2. मुझे चिकित्सा प्रणाली और चिकित्सा के उपरान्त होने वाले संभावित नतीजों के बारे में दत चिकित्सक के द्वारा अच्छी तरह समझाया गया है।

3. मुझे चिकित्सा के दौरान अथवा उसके उपरांत होने वाली संभावित/ अप्रत्याशित हानियों, इलाज के समय उपयुक्त होने वाली दवा व उसके प्रयोग के बारे में भी अच्छी तरह बताया गया है।

4. रोगी के द्वारा चिकित्सा के बीच में ही छोड़कर जाने अथवा चिकित्सा के उपरान्त परिणाम के उम्मीद के अनुसार न आने पर, चिकित्सक की जिम्मेदारी नहीं होगी।

5. मै पुनः अपनी सहमति देता हूँ कि इस रिकार्ड को भविष्य में चिकित्सीय शोध, प्रशिक्षण एवं चिकित्सा प्रणाली के उत्थान के लिये प्रयोग किया जा सकता है।

रोगी के हस्ताक्षर

तारीख:

CONSENTFORM

SANTOSH
Deemed to be University
(Established u/s 3 of the UGC Act, 1956)

Department of Orthodontics and dentofacial orthopedics

INFORMED CONSENT FORM

1. I, age_ son/daughter of R/Ogives full consent for the examination, investigation and the treatment, without any compulsion of any kind.

2. Doctor has fully explained to me the purpose of the procedure(s), the predictable and unpredictable consequences of the procedure, drug administered if any including the use of local anesthesia , and has also informed me of expected benefits and complications (from known and unknown causes), discomforts and risks that may arise as well as possible alternatives to the proposed treatment including no treatment. The risks of no treatment have also been discussed. I have been given an opportunity to ask questions and all my questions have been answered fully and satisfactorily.

3. I understand that during the course of the procedure(s), unforeseen conditions may arise which necessitates procedures different from those contemplated. I, therefore, consent to the performance of additional procedures that the above-named dentist or his/her associate may consider necessary.

4. I acknowledge that no guarantee or assurances have been made to me concerning the results intended from the procedure(s).

5. No identity lies with the doctor in case the treatment is discontinued or the outcome is not as predicted.

6. I confirm that I have read and fully understand the above and that all blank spaces have been completed prior to my signing. I give my consent that this record can be used for research, education, training & up liftment of the dental profession.

Signature of patient

Date:

ANNEXURE – II

Linear measurements Master Chart

sr no	inter canine width			IST INTER PM WIDTH			2ND INTER PM WIDTH			1ST IM WIDTH MC			1ST IM WIDTH DC			1ST IM WIDTH TP			2ND IM WITH MC			2ND IM WIDTH DC			2ND IM WIDTH TP		
	TI	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	T1	T2	T3	TI	T2	T3	T1	T2	T3
1	30	33	32	37	41	40	45	47	46.5	47	49	48	49	51	50	31	33	32	53	56	54.5	55	57	55.5	35	36	35.5
2	28	32	30.5	37	39	38	42	45	44.5	48	50	48.5	50	51	50	34	35	34.5	52	54	53.5	55	56	55.5	37	39	38.5
3	28.5	30	29	37	38.5	38	40	42	41	46	49	48	48	49.5	49	32	34	33.5	50	52	51	52	53.5	53	35	36.5	36
4	35	37	36	41	42.5	41.5	48	49.5	48.5	48.5	50	49	52.5	54	53	33	35	34	56	58	57.5	58	59	58	39	41	40
5	35	37.5	37	42	44	43	44	46	45	45	47.5	46.5	47.5	49.5	48.5	33	33.5	33.5	50	52	51	53.5	55	54	37	39.5	38.5
6	32	34	33	40	42	41	45	47	46	49.5	52	51	52	54	52	35	36	35	56	58	56.5	57	59	57	41	42	41
7	32	34	33	43	45	44	46	48	47	49	50	49	52	53	52	36	39	37	55	57	56	56	58	56	40	42	41
8	33	35	34	41	42	41	45	48	46.5	46	48	46	48	50	50.5	35	36	35	51	52	53	53	54	55	39	40	39
9	30	34	33	40	42	41	45	47	46.5	50	53	51	53	55	53.5	37	39	39	55	57	56	56	58	57.5	40	43	42.5
10	32	35	34	41	43	41.5	46	48	46.5	51	52	51	54	56	54.5	36	38	36	58	59	58.5	59	60	60.5	40	42	40
11	37	39	38	41	44	43.5	44	46	45.5	47	50	49	48	52	51.5	30	33	32	57	59	58	58	60	59	38	40	39
12	38	41	40	48	51	50	50	52	51	52	54	53.5	52	54	53.5	35	38	36.5	60	62	62	61	63	62.5	43	45	44

Inclination Master Chart

Crown Inclination 14			Crown Inclination 15			Crown inclination 16			Crown Inclination 24			Crown Inclination 25			Crown Inclination 26		
T1	T2P	T2a	T1	T2p	T2a	T1	T2p	T2a	T1	T2p	T2a	T1	T2p	T2a	T1	T2p	T2a
82	82.5	82	79	80	80	74	76	75	81	83	86	77	77	77	72	75	74
86	88.5	87	83	87	85	81	81.5	81	85	86	85.5	83	83.5	84	81	84	85
76	79	78	80	82	82	86	87	72	73	75	75	75	77	77	81	83	83
88	89	88	81	80	82.5	78	79	76	79	78	80	78	78	79	80	80	80
85	86.5	86	83	84	83	73	76	74.5	80	82	81	75	78	76	70	72	71
82	84	84	80	80	80	74	76	75	84	86	86	79	80	80	75	77	76
84	84.5	85	81	78	82.5	72	72	74	77	76	81	75	76.5	82	72	74	73
82	83	83	80	80.5	80.5	71	72	71	79	77	78	74	78	75	70	71.5	0.5
81	81	81	79	79	79	80	82	81	82	83	83	84	85	85	84	86	86
80	80	80	79	79	79	78.5	79	78	81	80	84	76	76.5	79	76	76	76
86	88	87	82	81.5	82	75.5	77	76	88	87	84	80	83.5	80	78	79	78
86	87	86	75.5	76	76	74	76	75	77.5	76	75.5	72	73	73	76	80	77

Male vs Female

				MALE T1						FEMALE T1				
INTERCANINE WIDTH		32	38	30	34	37		32	30	30	33	28.5	35	31
INTER 1ST PM WIDTH		40	48	39	41	41		43	32	40	41	40	42	38
INTER 2ND PM WIDTH		45	50	45	46	44		46	42	45	45	37	43	42
INTER IST MOLRMC		49.5	52	47	51	47		49	48	50	46	47	45	49
INRER IST MOLAR DC		52	55	49	54	48		52	50	53	48	48	47.5	51
INTER IST MOLAR TP		35	35	31	36	30		36	34	37	35	32	33	32
INTER 2ND MOLAR MC		56	60	53	58	37		55	52	55	51	50	50	54
INTER 2ND MOLAR DC		57	61	54	59	58		56	55	56	33	52	53.5	53
INRER 2ND MOLAR TP		41	43	35	40	38		40	37	40	39	35	37	37
				MALE T2p						FEMALE T2p	2p			
INTERCANINE WIDTH		34	41	33	35	39		34	32	34	35	29.5	37.5	33
INTER 1ST PM WIDTH		42	51	41	43	44		45	39	42	42	41.5	44	40
INTER 2ND PM WIDTH		47	52	47	48	46		48	44.5	47	48	38.5	45	45
INTER IST MOLRMC		52	54	49	52	50		50	49.5	53	48	49	47.5	51
INRER IST MOLAR DC		54	58	51	56	52		53	51	55	50	49.5	49.5	53
INTER IST MOLAR TP		36	38	33	38	33		38	35	39	36	39	33.5	34
INTER 2ND MOLAR MC		58	62	56	59	59		57	54	56	53	51.5	52	56
INTER 2ND MOLAR DC		59.5	63	57.5	60	60		58	56	58	55	53.5	55	55
INRER 2ND MOLAR TP		42	45	36	42	40		42	39	43	40	36.5	39.5	39
				MALE T2a								FEMALE 2a		
INTERCANINE WIDTH		33	40	32	34	38		33	30.5	33	34	29	37	32
INTER 1ST PM WIDTH		41	50	40	41.5	43		44	38	41	41	41	43	31.5
INTER 2ND PM WIDTH		46	51	46.5	46.5	45.5		47	44	46.5	46.5	38	44	44.5
INTER IST MOLRMC		51	53.5	48	51	49		49	48.5	51	46	48	46.5	50
INRER IST MOLAR DC		52	57	50	54.5	51.5		52	50	53.5	48.5	49	48.5	52
INTER IST MOLAR TP		35	36.5	32	36	32		37	34.5	39	35	33.5	33.5	33.5
INTER 2ND MOLAR MC		56.5	62	54.5	58.5	58		56	53.5	56	52	51	51	55.5
INTER 2ND MOLAR DC		57	62.5	55	59.5	59		57	55.5	57.5	54	53	54	54
INRER 2ND MOLAR TP		41	44	35.5	40	39		41	38.5	42.5	39	36	38.5	38.5

Right Quadrant vs Left Quadrant

			RIGHT SIDE														LEFT SIDE										
			T1														T1										
CROWN INC IST PM	IST PM		82	86	76	88	85	82	84	82	81	80	86	86		81	85	73	79	80	84	77	79	82	81	88	77.5
CROWN INC 2ND PM	2ND PM		79	83	80	81	83	80	81	80	80	79	82	75.5		77	83	75	78	75	79	75	74	84	76	80	7281
CROWN INC ISTM	IST M		74	81	86	78	73	74	72	71	80	78.5	75.5	74		72	81	81	80	70	75	72	70	84	76	78	76
			T2p														T2p										
CROWN INC IST PM			82.5	88.5	79	89	86.5	84	84.5	83	81	80	88	87		83	86	75	78	82	86	76	77	83	80	87	76
CROWN INC 2ND PM			80	87	82	80	84	80	78	80.5	79	79	81.5	76		77	83.5	77	78	78	80	76.5	78	85	76.5	83.5	73
CROWN INC IST M			76	81.5	87	79	76	76	72	72	82	79	77	76		75	84	83	80	72	77	74	71.5	86	76	79	80
			T2a														T2a										
CROWN INC IST PM			82	87	78	88	86	84	85	83	81	80	87	86		86	85.5	75	80	81	86	81	78	83	84	84	75.5
CROWN INC 2ND PM			80	85	82	82.5	83	80	82.5	80.5	79	79	82	76		77	84	77	79	76	80	82	75	85	79	80	73
CROWN INC IST M			75	81	72	76	74.5	75	74	71	81	78	76	75		74	85	83	80	71	76	73	70.5	86	76	78	77

ANNEXURE – III

SANTOSH
Deemed to be University
(Established u/s 3 of the UGC Act, 1956)

F. No. SU/2023/2480[16] Dated: 26.09.2023

Subject: Grant of Ethical Clearance for Thesis Protocol Topic "Assessment of the Efficacy of clear Aligner Therapy for Maxillary Expansion", submitted by **Dr. PUJA KUMARI,** MDS student of Batch 2022-2023, Department of **ORTHODONTICS & DENTOFACIAL ORTHOPAEDICS.**

*****

With reference to his/her request for grant of Ethical Clearance for the Thesis Protocol entitled "Assessment of the Efficacy of clear Aligner Therapy for Maxillary Expansion", **Dr. PUJA KUMARI** is informed that the Thesis Protocol submitted by him/her was considered by the **Screening Committee** of the Santosh Dental College & Hospital in its meetings held on 07.02.2023 & 08.02.2023. The recommendations of the **Screening Committee** were considered in detail by the Institutional **Ethics Committee** in its meeting held on **23.09.2023** and the same was **approved** by the **Ethics Committee.**

He /She is informed accordingly for further necessary action.

[DR. NARESH SHARMA]
REGISTRAR

SANTOSH "DEEMED TO BE UNIVERSITY" REGISTRAR GHAZIABAD, (U.P.)

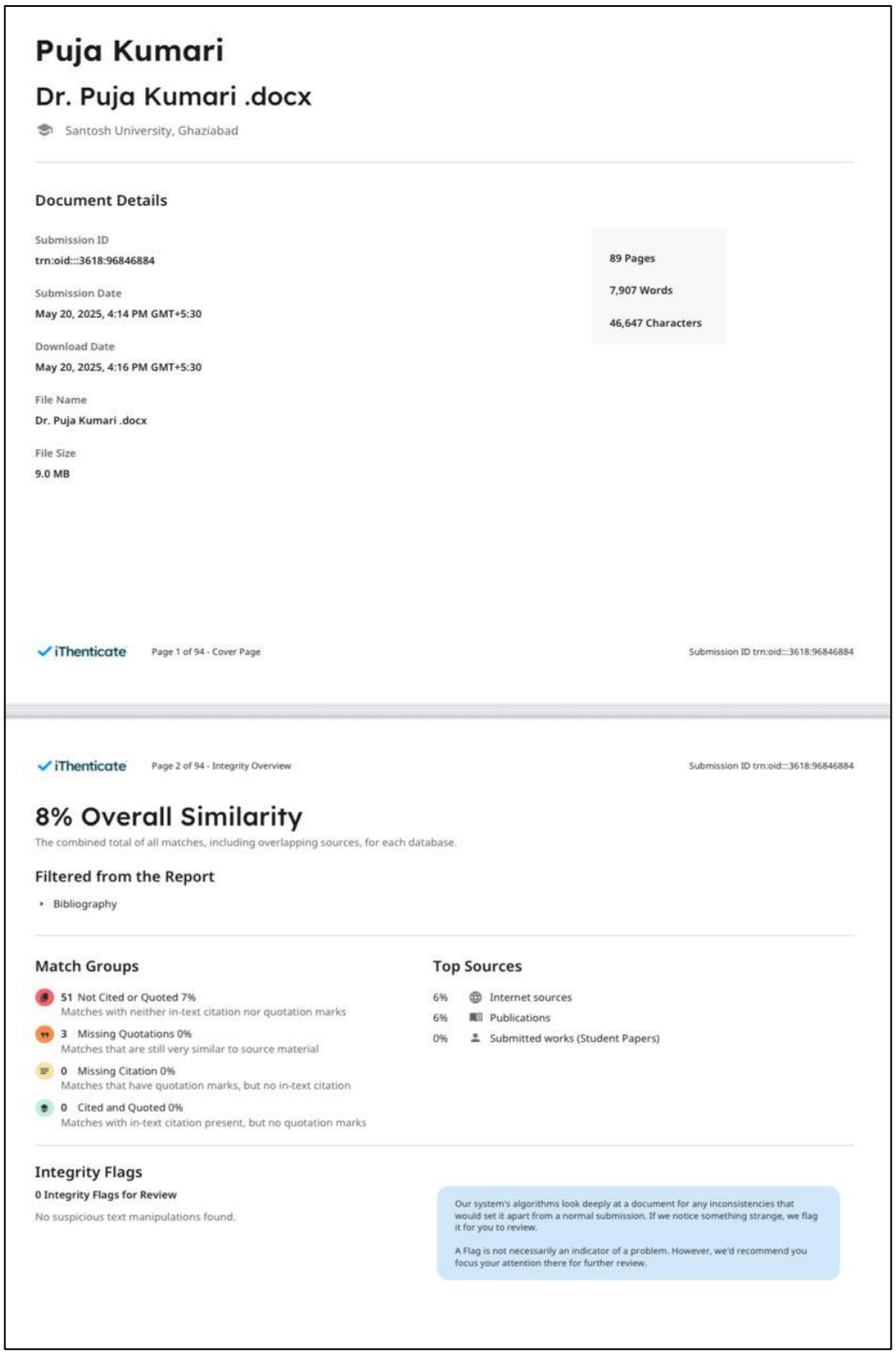
Dr. PUJA KUMARI
MDS student of batch 2022-2023
Department of ORTHODONTICS & DENTOFACIAL ORTHOPAEDICS
Email: pujasbb242@gmail.com

Copy to:

1. The Vice Chancellor
2. The Dean, SDC&H
3. The Dean – Research
4. The Dean – Academics
5. The Director - IQAC
6. **Dr. Rajiv Ahluwalia** (Guide)
7. HOD of **ORTHODONTICS & DENTOFACIAL ORTHOPAEDICS**

ANNEXURE – IV

ANTI-PLAGIARISM CHECK REPORT



Puja Kumari

Dr. Puja Kumari .docx

Santosh University, Ghaziabad

Document Details

Submission ID
trn:oid:::3618:96846884

Submission Date
May 20, 2025, 4:14 PM GMT+5:30

Download Date
May 20, 2025, 4:16 PM GMT+5:30

File Name
Dr. Puja Kumari .docx

File Size
9.0 MB

89 Pages

7,907 Words

46,647 Characters

iThenticate Page 1 of 94 - Cover Page Submission ID trn:oid:::3618:96846884

iThenticate Page 2 of 94 - Integrity Overview Submission ID trn:oid:::3618:96846884

8% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

Filtered from the Report

- Bibliography

Match Groups

51 Not Cited or Quoted 7%
Matches with neither in-text citation nor quotation marks

3 Missing Quotations 0%
Matches that are still very similar to source material

0 Missing Citation 0%
Matches that have quotation marks, but no in-text citation

0 Cited and Quoted 0%
Matches with in-text citation present, but no quotation marks

Top Sources

6% Internet sources
6% Publications
0% Submitted works (Student Papers)

Integrity Flags

0 Integrity Flags for Review

No suspicious text manipulations found.

Our system's algorithms look deeply at a document for any inconsistencies that would set it apart from a normal submission. If we notice something strange, we flag it for you to review.

A Flag is not necessarily an indicator of a problem. However, we'd recommend you focus your attention there for further review.